Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2014:12e

Accident at Bromma Stockholm Airport on 4 November 2013 involving the aircraft SE-FLS of type Rockwell Commander-112.

File number L-158/13

8/29/2014

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring again, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

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This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

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Content

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring again, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 4 November 2013 that an accident involving an aircraft with registration SE-FLS, Rockwell Commander-112 had occurred at Stockholm/Bromma Airport, Stockholm County, that same day at 13.34.

The accident has been investigated by SHK represented by Mr Jonas Bäckstrand, Chairperson, Mr Stefan Christensen, Investigator in Charge, Mr Peter Swaffer, Operational Investigator, Mr Christer Jeleborg, Technical Investigator and Mr Urban Kjellberg, Investigator specialising in Fire and Rescue Services.

Mike Folkerts has participated as an accredited representative of the NTSB.

As advisor to the Swedish Transport Agency, Magnus Lundin has participated up until 12 February 2014, and thereafter Magnus Axelsson.

The following organisations have been notified: The European Aviation Safety Agency (EASA), the EU Commission, the National Transport Safety Board (NTSB) and the Swedish Transport Agency.

Investigation material

Interviews have been conducted with the pilot and the operations management staff from Swedavia at Stockholm/Bromma Airport.

The report has been limited under 1.6.1 to only reporting technical aircraft data of significance to the investigation.

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Aircraft:	
Registration and type	SE-FLS, Rockwell Commander-112
Class, airworthiness	Normal, Certificate of Airworthiness and valid ARC[1]
Owner	Bromma Air Maintenance, BAM
Time of occurrence	2013-11-04, at 13.34 in daylight Note: all times are given in Swedish standard time (UTC[2] + 1 hr)
Place	Bromma Stockholm Airport, Stockholm county, (position 5921N 01756E, 14 metres above sea level)
Type of flight	Private
Weather	According to Metar: wind 180° 10 kts, visibility over 10 km, clouds 3-4/8 with cloud base at 2,100 feet, temperature/dewpoint 8/5 °C, QNH[3] 986 hPa
Persons on board:	1
Crew including cabin	1
Passengers	0
Injuries to persons	None
Damage to aircraft	Significant
Other damage	Limited
Pilot:	
Age, licence	46 years, CPL[4]
Total flying hours	2,154 hours, of which 2 hours on type
Flying hours previous 90 days	51 hours, of which 2 hours on type
Number of landings previous 90 days:	2, of which 2 on type

[1] ARC (Airworthiness Review Certificate).
[2] UTC (Coordinated Universal Time) is a reference for the exact time anywhere in the world.
[3] QNH indicates barometric pressure adjusted to mean sea level.
[4] CPL (Commercial Pilot License).

SUMMARY

One week before the accident, the aircraft in question flew for the first time in a number of years. The intention was to carry out a functional check flight and to transport the aircraft from Norrköping to Stockholm/Bromma Airport.

The pilot, who also later conducted the flight that ended in an accident, has stated that he chose to remain in the proximity of the airport so as to check certain functions before the onward flight. A false fault indication from the landing gear resulted in the tower issuing a warning alarm.

The pilot decided to return to Norrköping Airport and the landing was normal. However, the pilot perceived that the aircraft swerved when setting down the nose wheel. The swerving and its subsequent consequences came to be the object of the accident that the ongoing report primarily concerns.

On 4 November 2013, the second attempt to fly to Stockholm/Bromma Airport was commenced. The flight and approach to runway 12 at Bromma were normal. During landing when the nose wheel was set down, the aircraft swerved and the pilot had difficulties holding the aircraft on a steady course. The aircraft swerved along the runway centre line and finally left the runway, knocking down a sign.

The pilot has stated that he did not brake as he realized the risk of incorrect usage of the brakes could have intensified the swerving, which he feels could have aggravated the situation.

Having informed the tower of the occurred and of the fuel leakage from the right wing, the pilot then shut down the engine, cut the power supply and left the aircraft. The airport's rescue services covered the spilled fuel with foam so as to prevent ignition. No fire arose.

Safety recommendations

The FAA is recommended to:

- Provide information on the connection between an imbalance in the nose wheel and nose wheel shimmying. *RL 2014:12 (R1)*

EASA is recommended to:

- Provide information on the connection between an imbalance in the nose wheel and nose wheel shimmying. *RL 2014:12 (R2)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

One week before the accident, the aircraft in question flew for the first time in a number of years. The aircraft – see figure 1 – had until this point stood parked at Norrköping Airport whilst undergoing extensive maintenance.

Figure 1. Aircraft SE-FLS. Photo: Juha Ritaranta

According to the owner, the intention was to carry out a functional check flight and to transport the aircraft from Norrköping to BAM, Bromma Air Maintenance, at Stockholm/Bromma Airport for further maintenance. The pilot, who also later conducted the flight that ended in an accident, has stated that he chose to remain in the proximity of the airport so as to check certain functions before the onward flight. A false fault indication from the landing gear resulted in the tower issuing a warning alarm which is normally used to prepare in the event of an accident.

The pilot decided to return to Norrköping Airport and the landing was normal insofar as the landing gear seemed to be fully extended. However, the pilot perceived that the aircraft swerved when setting down the nose wheel. The swerving and its subsequent consequences came to be the object of the accident that the ongoing report primarily concerns.

The pilot made a verbal remark on the swerving to the maintenance workshop. There is however no documentation of this, nor whether or not the workshop carried out any measures in response to the remark. Where the landing gear is concerned, this was a matter of a micro switch that needed to be adjusted.

1.1.2 Sequence of events

On 4 November, the second attempt to fly to Stockholm/Bromma Airport was commenced. The flight was conducted with somewhat limited equipment in terms of flight instruments. The radio communication, for example, was conducted via a hand-held radio. The aircraft was however equipped according to applicable requirements. According to the pilot, the limitation did not hinder the handling of the aircraft.

The flight and approach to runway 12 at Bromma were normal. During landing when the nose wheel was set down, the aircraft swerved and the pilot had difficulties holding the aircraft on a steady course.

In figure 2, we can follow how the aircraft swerved along the runway centre line and finally left the runway, knocking down a sign with the right wing. The swerving along the centre line is according to the pilot's estimations. The image does however provide an outline of the events. The blue arrow marks the aircraft's final position and heading.

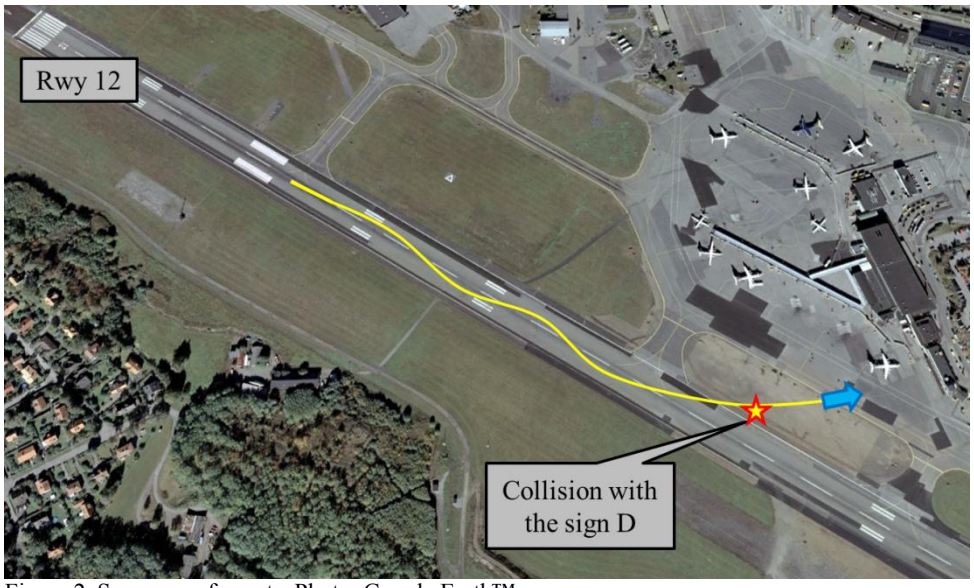

Figure 2. Sequence of events. Photo: Google Earth™

The wind resulted in a crosswind component of around 8 knots from the right. The pilot has stated, however, that the wind did not constitute a problem and that the latter part of the approach was conducted along an extension of the centre line. He has also stated that there was no lateral force in the form of gusts or kinetic energy resulting from a diagonal approach.

The pilot has stated that he did not brake as he realized the risk of incorrect usage of the brakes could have intensified the swerving, which he feels could have aggravated the situation.

The yellow arrow in figure 3 shows roughly the flight path seen from the pilot's perspective. The sign D is also marked in the image.

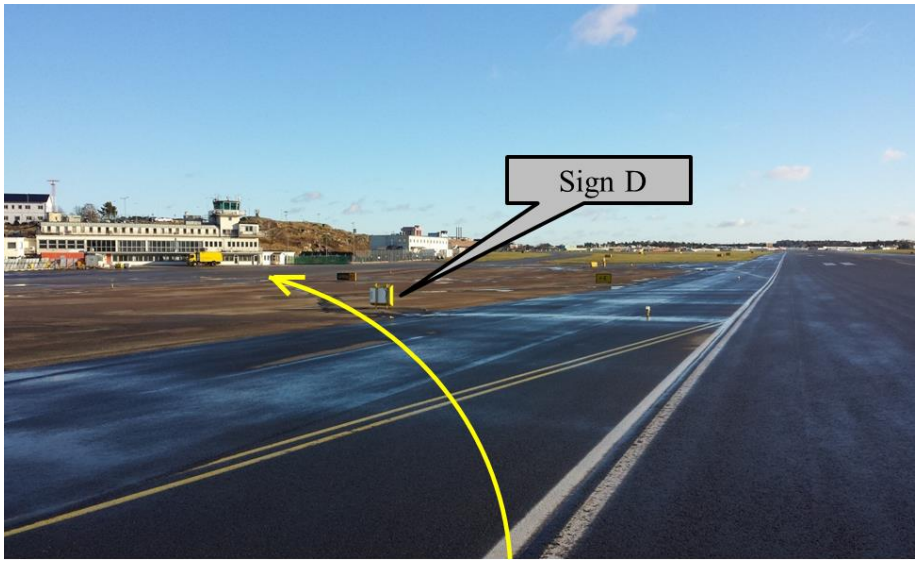

Figure 3. Flight path from the pilot's perspective. Photo: Swedavia.

Having informed the tower of the occurred and of the fuel leakage from the right wing, the pilot then shut down the engine, cut the power supply and left the aircraft.

The airport's rescue services covered the spilled fuel with foam so as to prevent ignition. No fire or other damage arose. One hour after the accident, the aircraft was towed to a hangar and the airport could then, following a check of the runway with no remarks, reopen for traffic after having been closed for over two and a half hours.

The accident occurred at position 5921N 01756E, 14 meters above sea level.

1.2 Injuries to persons

	Crew members	Passengers	On board	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	-
None	1	0	1	-
Total	1	0	1	-

1.3 Damage to aircraft

Significant.

1.4 Other damage and environmental impact

The sign that the aircraft collided with (see figure 4) was destroyed and collapsed as intended – i.e., as per the design of the lower part of the legs. The left-hand photo shows the rear of the sign; the side which the aircraft struck.

Figure 4. Sign D incl. fracture surface of legs. Photo: Swedavia.

No other damages have been reported, except for the leakage of fuel from the right wing tank. The airport's rescue services took measures to protect storm drains and power ports from the fuel spillage. The airport informed Stockholm Vatten AB of the risk that spilled fuel may have entered the storm drain conduits.

1.5 Crew

1.5.1 Pilot

The pilot, 46 years, had a CPL with valid operational and medical eligibility.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	1	24	51	2,154
This type	1	0	2	2

Number of landings this type previous 90 days: 2.
Last PC[5] conducted on 31 January 2013 on Cessna 172.

1.6 Aircraft

1.6.1 Aircraft data

Aircraft	
TC-holder	Commander Aircraft Corporation, New Jersey, USA
Type	Rockwell Commander-112
Serial number	350
Year of manufacture	1975
Gross mass, kg	Max authorized take off mass1200, actual 998
Centre of gravity	Within permitted area.
Total flying time, hrs	1,494
Operating time since overhaul, hrs	2
Fuel loaded	130 litres of type AVGAS 100LL

[5] PC (Proficiency check).

Engine	
TC-holder	Lycoming Engines, Pennsylvania, USA
Engine type	IO-360-C1D6
Engine	***No 1***
Serial number	L-14315-51A
Outstanding remarks	
One outstanding remark which had no bearing on the incident	

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 Description of parts or systems related to the accident

- Nose wheel steering

In order to maneuver the aircraft on the ground, there are cables running between the nose gear and the rudder pedals. The rudder is also maneuvered by these. The nose wheel is mechanically centered when the shock absorber is fully extended, regardless of the rudder pedal displacement.

- Shimmy damper

Nose wheel shimmy is when the wheel oscillates. A shimmy damper is installed in order to prevent this. The damper can counteract oscillations and vibrations up to a certain limit.

- Wheel brakes

The main wheels are equipped with hydraulic brakes that are maneuvered individually with the upper section of the rudder pedals.

- Rudder

Pilots with experience of the aircraft type have stated that the rudder has less effect than what is generally expected of an aircraft of this class.

According to the pilot's operating handbook for the aircraft, the highest demonstrated crosswind component is 12 knots. On comparable aircraft in the same class, the corresponding value is between 15 and 17 knots.

1.7 Meteorological information

According to Metar: Wind 180° 10 knots, visibility over 10 km, clouds 3-4/8 with cloud base at 2,100 feet, temperature/dewpoint 8/5°C, QNH 986 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Radio communications

The pilot maintained radio communication using a handheld radio. Air traffic control was notified of this in advance.

1.10 Aerodrome information

The airport had operational status in accordance with the Swedish AIP[6].

1.10.1 Sign D

The sign that the aircraft collided with was a directional sign. It was intended to indicate that a taxiway adjoins the actual runway. The design, dimensions, mounting height and installation of the sign were in accordance with accepted standards.

In accordance with Chapter 10, Section 5 of the Swedish Transport Agency's Regulations and General Advice (TSFS 2010:133) on Visual Aids for Navigation at an Airport, signs such as this must be of a brittle construction and little mass. Permission for the placement of the sign was established in accordance with an application for installation, and followed the provisions of Chapter 10, Section 6 of the aforementioned provisions; see the table in figure 5.

Skylthöjd i millimeter				Avstånd från taxibanans markerade kant till kant på skylt	Avstånd från banans markerade kant till kant på skylt
Kod-siffra	Tecken höjd	Skylt-dimension i höjdled (minst)	Mont-eringshöjd (max.)		
1 eller 2	200	400	700	5–11 meter	3–10 meter
1 eller 2	300	600	900	5–11 meter	3–10 meter
3 eller 4	300	600	900	11–21 meter	8–15 meter
3 eller 4	400	800	1 100	11–21 meter	8–15 meter

Figure 5. TSFS's table of placement distances for signs.

The green rectangle shows the values that apply to Bromma Stockholm Airport in terms of classification for installations of directional signs. The code 3 is based on the maximum weight of aircraft that the airport is permitted to handle (the number relates to the type of aircraft). This number in turn dictates the dimension and installation of a sign, as well as its distance to the edge of the runway.

1.11 Flight recorders

Not required.

[6] AIP – Aeronautical Information Publication.

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

The site of the accident was between runway 12 and the apron, in the northern part of the "Teddy green"; see figure 2. The location has received this name over the years from air traffic controllers and pilots, and had no signs in or around it until just a few years ago. The aircraft stopped just a meter or so short of the taxiway that lies on the north side of "Teddy green".

1.12.2 Aircraft wreckage

The aircraft received considerable damage, primarily on the right wing; see figure 6. There was also minor damage to the body of the aircraft just in front of the right wing mounting.

The aircraft was lined up at the site of the accident and then towed by Swedavia to a nearby hanger following conclusion of the rescue efforts.

Figure 6. Damage to SE-FLS's right wing.

1.13 Medical information

Nothing indicates that the mental or physical condition of the pilot were impaired before or during the flight.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Provisions on rescue services

Provisions on rescue services are found primarily in the Civil Protection Act (2003:778, Swedish abbrev. LSO) and the Civil Protection Ordinance (2003:789, Swedish abbrev. FSO).

According to Chapter 1, Section 2, first paragraph of LSO, the term "rescue services" denotes the rescue operations for which central government or municipalities shall be responsible in the event of accidents and imminent danger of accidents in order to prevent and limit injury to persons and damage to property and the environment. Central government is responsible for mountain rescue services, air rescue services, sea rescue services, environmental rescue services at sea, and rescue services in case of the emission of radioactive substances and for searching for missing persons in certain cases. In accordance with Chapter 3, Section 7 of LSO, the respective municipality is responsible for rescue services in any case other than that of a national rescue.

1.15.2 Alarm management

Provisions that concern alarm services for air traffic control can be found in LFV's (Luftfartsverket, the Air Navigation Services of Sweden) central and local ANS[7] operational manuals. It was the edition from 10 May 2012 that applied for the Central Operations Manual and the local operational manual for Bromma Stockholm Airport was dated 4 April 2013. The appendix to the Central Operations Manual, with guidance for alerting, states that accident alarms (red checklist) shall be used in connection with the aircraft exiting the runway during take-off or landing. Chapter 4, Section 7 of the Swedish Transport Agency's Regulations and General Advice (TSFS 2010:111) on Air Rescue Services states that warning alarms (green checklist) are used when the aircraft is in danger in the proximity of an airport.

The air traffic controller that provided the ATS[8] from the control tower (TWR) at Bromma Stockholm Airport triggered a warning alarm at 13.34 in accordance with the green checklist[9] in connection with the sighting of the aircraft exiting the landing strip. When it was clear to the air traffic controller that the aircraft had collided with a sign, the crash became fact. No transition to "crash with identified site of accident" (red checklist) was initiated; this despite the fact that the green checklist states that the transition to a red checklist is a measure to be taken in the event of a crash. The pilot called the TWR after the occurence and informed of what had happened, explaining that fuel had leaked from the aircraft.

[7] ANS – Air Navigation Services.
[8] ATS - Air Traffic Services.
[9] Green checklist – found in the instructions for the rescue services at Bromma Stockholm Airport.

The airport's rescue services were alerted from the TWR via the triggering of a warning alarm. The information provided in connection with the alarm stated that there was a person on board and that the aircraft was leaking fuel. The rescue operations coordinator thus urged the air traffic controller to have the pilot leave the aircraft immediately. The instruction was also forwarded by the TWR.

At the SOS centre, which also received the warning alarm from the airport, the SOS operator called JRCC[10] at 13.35. At the same time, the air traffic controller from TWR called JRCC and informed them of the occurence. According to the checklist, this contact shall take place via the SOS centre, which in turn shall initiate a three-party conversation with JRCC and TWR. Information on the occurence communicated to JRCC from the TWR was then also forwarded to the SOS centre.

At 13.36, after having received information on the occurence via the SOS centre, the Greater Stockholm Command and Control Centre (SSRC) and fire stations Johannes, Solna and Kista were alerted. Two ambulances were alerted from the SOS centre in Stockholm.

1.15.3 Rescue operations at the site of the accident

The rescue operations coordinator could see the fuel leakage (AVGAS 100LL[11]) for himself when the airport's response team arrived at the aircraft. At this point, he notified the TWR that Bromma Stockholm Airport needed to be closed off to traffic due to the scope of the incident. Using the fire engine's siren and visual instructions, the rescue operations coordinator was able to gain the pilot's attention and signal that he was to leave the risk area and find a safer location. Once the pilot had left the aircraft, the fuel continued to leak out onto the ground and the spill was protected against ignition by means of covering it with foam. Following an assessment of the risks surrounding the fuel spill, the site of the damages was divided into zones and attempts were made to stop the leak. The first unit from the municipal rescue services came from Solna and arrived at the airport at 13.42.

The rescue operations coordinator from the municipal rescue services worked at the established control point together with police, medical personnel and representatives of the airport. It was decided that the aircraft would be towed from the airport under supervision of a fire engine. A plan was also made together with the airport's environmental department for how the fuel emissions would be addressed and taken care of. The emission was estimated to total around 100 litres of fuel.

[10] JRCC – Joint Rescue Coordination Centre.
[11] AVGAS 100LL - Fuel which is a highly flammable liquid and emits combustible gases from around -30 °C.

Following the recommendations of airport personnel, the rescue operations coordinator agreed to the airport's "vacuum trucks" – which are normally used to take up liquid used for de-icing[12] aircraft – being used to clear up the spilled fuel. According to information provided to SHK by the airport, this type of vehicle is not approved for handling flammable products such as fuel. Whilst awaiting sludge pump trucks that could take care of the fuel spillage, the vacuum trucks were used to take up fuel and empty it in the pond normally used for de-icing fluid. At the pond, supervision of a fire engine was arranged so as to prevent the ignition of any combustible gases. Once the ground spillage had been taken care of, the rescue operation was concluded at around 4pm, and the airport opened again for traffic around fifteen minutes later.

1.15.4 Evacuation

The pilot left the aircraft via one of the doors once he had cut the engine and shut off the power supply.

1.16 Tests and research

1.16.1 Technical examinations

General background

Certain manufacturers of nose wheel rims state in the respective manual that balancing may be desirable, especially if the diameter is larger than 254 mm. If operators choose to balance the wheel, dynamic balancing is recommended. For rims smaller than 254 mm, static balancing can be used as an alternative method.

Specific background

The pilot had previously made verbal remarks on minor swerving of the nose wheel when landing. Extensive maintenance had recently been carried out prior to these flights; tire and inner-tube had been changed on the nose wheel.

Examination of the nose gear including wheel

Troubleshooting tips in MM[13], Chapter 6, provides four possible causes of shimmying. Loose or worn wheel bearings, imbalance in the wheel, worn bolts or torque link bushings, and the shimmy damper being loose.

SHK has conducted a technical examination of the aforementioned areas. The nose wheel was dismounted from the aircraft and placed in static balance equipment. The wheel clearly showed a static imbalance. There were no other remarks.

[12] De-icing fluid gives off combustible gases at temperatures exceeding 100 °C.
[13] MM - Maintenance Manual.

MM states that the rim is balanced from manufacturing and that the tire and inner-tube are individually marked by the manufacturer. These markings must be positioned in accordance with the instructions in MM for the wheel to be balanced. The inner-tube was correctly installed in the tire.

The balancing showed that 52 g was required on the outer edge of the rim in order to achieve static balance. The rim was also checked without tire and inner-tube, whereby it was found that 20 g were required to achieve balance. MM contained no requirements for balancing to be carried out after changing tire and inner-tube.

Rigging of nose wheel and rudder in relation to pedals.

During the examination, the rudder and nose wheel were centered. Measurements were taken and there was a difference between the pedals on the right side of around 50 mm. On the left side, where the pilot sat, a difference of around 25 mm was measured. In both cases, centering of the pedals would have produced a right turn.

Examination of wheel brakes

A simple examination was carried out to verify that none of the brakes were jamming. The brakes passed without remark.

1.16.2 Interview with the pilot

SHK has interviewed the pilot. His information is in line with the sequence of events presented under 1.1.

1.16.3 Interviews with Swedavia's Director of Security and Safety

In connection with one of the visits SHK made to Bromma due to the accident, Swedavia's Director of Security and Safety was interviewed. At the time of the accident, he sat in a building right in front of the aircraft's final position and could follow the final stages of the event. He has therefore been able to verify the sequence of events itself and what happened thereafter.

1.17 The operator's organisation and management

Not applicable.

1.18 Additional information

Bromma Air Maintenance, which owned the aircraft, is a maintenance organization based in Stockholm/Bromma Airport. Maintenance work was carried out both there and in the company's premises at Norrköping Airport.

The company does not have permission for commercial air traffic but had a number of years ago acquired SE-FLS for maintenance and

restoration. The intention was either to sell the aircraft once it was in good shape or to keep it for transportation of its personnel.

1.19 Special methods of investigation

Not applicable.

2. ANALYSIS

2.1 The initial flight

Considering the aircraft's long period of inactivity and the extensive maintenance work, the pilot was wise to remain in the proximity of Norrköping Airport initially. Functional checks of various systems were carried out before the onward flight to Bromma could take place. The fact that a malfunction occurred – in this case a false fault indication from the landing gear – is not uncommon in such circumstances.

The observation of the swerving when landing was remarked upon verbally by the pilot to the maintenance workshop. This procedure is not uncommon in itself, but a written report could have been more effective as it would likely have elicited a more active response. A written remark means that the maintenance workshop is responsible for carrying out measures, the results of which must be documented.

SHK finds it highly likely that the imbalance identified in the nose wheel which caused the accident was also the reason for the swerving which the pilot perceived during the first flight.

SHK also finds that there was a higher risk involved due to the functional check flight being carried out by a pilot who was inexperienced on the type – especially considering that the characteristics of the rudder of this aircraft differ from those of the types the pilot has experience with.

2.2 The accident

SHK does not consider the aircraft's limited equipment to have had any impact on the incident. The aircraft had a valid Certificate of Airworthiness and the fact that the radio communication was carried out using a handheld unit was not considered to have had a negative impact.

During the approach, which according to the pilot's information was normal, there was a crosswind component from the right side of around 8 knots. It is not likely that the wind would have had a great enough impact to have contributed to the aircraft's swerving along the centre line during landing.

The imbalance measured in the nose wheel was deemed to be the cause of the swerving. Imbalance in a nose wheel causing shimmying

when landing, which in turn results in yaw oscillation, is a well-known phenomenon. In the event in question, the effect was great enough to cause difficulties for the pilot in maintaining control of the aircraft.

The pilot was inexperienced on the aircraft type, and the accident occurred during his second landing. Pilots with experience on the type have remarked that considerably greater rudder deflection than on similar aircraft in this class is required in order to achieve the desired effect. The fact that the maximum permitted crosswind for landing is lower than for similar aircraft supports SHK's assessment that the pilot's lack of experience of the characteristics of the aircraft's rudders contributed to the sequence of events.

During SHK's investigation, it was also found that there was a certain difference between the pedals in terms of their neutral position. The difference was 25 mm in both directions and would have resulted in the nose wheel steering slightly to the right (i.e., for a right turn) if the pedals were centered. In other words, the left pedal was positioned somewhat further forward in order to keep the rudder and the nose wheel centered.

The effect of this has been analyzed in terms of its impact on the ability to keep the aircraft on a steady course along the runway. SHK's assessment, however, is that this had a negligible impact. The pilot's management of the pedals or the operational aspect that their asymmetrical positions could have entailed is therefore not considered to have had a negative impact.

It cannot be ruled out that the incident could have ended more favorably if the brakes had been used. Braking would likely have reduced the speed and contributed to the pilot regaining control of the aircraft.

2.3 Technical status

At the time of the accident, the nose wheel was impaired by an imbalance. The investigation did reveal, however, that the wheel was correctly assembled during the change of tire and that the work was carried out in accordance with the applicable instructions.

2.4 Rescue operation

2.4.1 Alarm services

When reviewing LFV's Central Operations Manual, the Swedish Transport Agency's Regulations and General Advice on Air Rescue Services, and the checklist in the instructions for the rescue services at Bromma Stockholm Airport, it is clear overall that the intention is for the accident alarm as per the red checklist to be used for incidents in which an aircraft leaves the runway in connection with landing. The measure given in the red checklist involving the accident alarm, which

must be observed in accordance with the planning, is considered to be suitable and appropriate.

The fact that the applicable checklists were not fully followed, and the fact that only one warning alarm was triggered from TWR, are not considered to have had a significantly negative impact on the rescue efforts from public rescue services. The fact that there were no serious consequences can likely be attributed to the sequence of events being of a relatively static nature, despite the fuel leakage from the aircraft, and to the lack of any personal injury and only one person being on board the aircraft. The resources that were alerted to the incident were more than sufficient for the rescue operations.

2.4.2 Handling emissions

The airport's vacuum trucks, which are normally used to take up de-icing fluid, were used to remove the fuel spilled on the ground as a result of the accident. The characteristics of the two different types of liquids differ markedly in terms of the fire hazard. At the outdoor temperature of 9 °C prevailing at the time of the accident, fuel over a free liquid surface emits combustible gases which can be ignited (e.g., by a spark) and begin to burn. With de-icing fluid, by comparison, a corresponding free liquid surface must have a temperature in excess of 100 °C in order for combustible gases to be generated and ignited. It is therefore not possible for de-icing fluid to be ignited by a vacuum truck as the necessary conditions of temperatures in excess of 100 °C are not normally present.

In connection with using the vacuum trucks to remove the spilled fuel, it cannot be ruled out that the personnel and equipment were at risk as the vehicles used were not adapted and approved for handling fuel or similar products which are a considerable fire hazard. Using such equipment that is not adapted and approved for the purpose in terms of the substance's characteristics and the risks it entails means that dangerous conditions can be created and that a new accident can occur if the liquid's combustible vapors are for whatever reason ignited. Apart from sparking, static electricity can constitute a source of ignition.

From the information obtained, SHK finds the working methods described herein to be inconsistent with sufficient worker protection and safe conditions for the personnel who carried out the rescue operation at the site of the accident. There was a lack of an adequate risk assessment in terms of the use of the vacuum trucks. The risk of using the vacuum trucks is thereby not considered to have been observed to a sufficient extent during the rescue operations, which were led by the municipal rescue services.

3. CONCLUSIONS

3.1 Findings

a) The pilot was qualified to perform the flight.
b) The aircraft had a Certificate of Airworthiness and a valid Airworthiness Review Certificate.
c) During landing, the aircraft swerved in an oscillating motion along the centre line.
d) The aircraft collided with a directional sign after having run off the side of runway 12.
e) The sign D was built and positioned in accordance with applicable legislation.
f) The rudder effect is lower than on comparable aircraft in the same class.
g) The rollout was carried out without application of the brakes.
h) A static imbalance was measured in the nose wheel.
i) The maintenance manual did not contain instructions for balancing when mounting the tire with inner-tube onto the rim.
j) The air traffic controller in TWR did not make a transition to "crash with identified site of accident" – red checklist – once the crash had been established.
k) The airport's vacuum trucks, which were used to take up the fuel spillage, were not adapted to or approved for handling fuel.
l) The risk assessment at the site of the accident did not take into account the fact that the vacuum trucks were not adapted to or approved for handling fuel.

3.2 Cause of the accident

The accident was caused by the following factors:

- Imbalance in the nose wheel caused nose wheel shimmy which led to the pilot losing control of the aircraft.
- The brakes were not used during the sequence of events.
- The pilot's lack of experience on the aircraft type may have meant that insufficient force was applied to the rudder pedals.

4. RECOMMENDATIONS

The FAA is recommended to:

- Provide information on the connection between an imbalance in the nose wheel and nose wheel shimmying. *RL 2014:12 (R1)*

EASA is recommended to:

- Provide information on the connection between an imbalance in the nose wheel and nose wheel shimmying. *RL 2014:12 (R2)*

The Swedish Accident Investigation Authority respectfully requests to receive, by **1 December 2014** at the latest, information regarding measures taken in response to the recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Jonas Bäckstrand Stefan Christensen