Reports 96-002/96-004

Fairchild SA 227 Metroliners ZK-POB and ZK-SDA

Christchurch and Auckland Airports

12 and 18 January 1996

Abstract

On Friday 12 January and Thursday 18 January 1996, Metroliners ZK-POB and ZK-SDA respectively were involved in runway excursions after the pilot flying engaged the nosewheel steering during their landing runs. No injuries were sustained in either event and the damage to the aircraft was minor.

The causal factors identified were a malfunction of the nosewheel steering system and the pilots' perseverance with the use of an aircraft system which was unserviceable.

The safety issues identified in these incidents were the absence of a clear instruction to pilots on the control of the aircraft during its landing roll and the potential for the nosewheel steering system amplifier to fail before its potential to do so was detected. A safety recommendation was made in relation to each of these items.

Transport Accident Investigation Commission

Aircraft Incident Reports 96-002[1]/96-004[2]

Aircraft types, serial numbers and registrations:	**a.** Fairchild SA 227 Metroliner AC606B ZK-POB **b.** Fairchild SA 227 Metroliner AC641 ZK-SDA
Number and type of engines:	**a.** Two Garrett TPE 331-11U-611G **b.** Two Garrett TPE 331-11U-611G
Date and time:	**a.** 12 January 1996, 0006 hours [3] **b.** 18 January 1996 0735 hours
Location:	**a.** Christchurch Airport Latitude: 49° 29' S Longitude: 172° 32' E **b.** Auckland Airport Latitude: 37° 01' S Longitude: 174° 47' E
Type of flight:	**a.** Air Transport (Cargo) **b.** Air Transport Scheduled (Passenger)
Persons on board:	**a.** Crew: 2 Passengers: Nil **b.** Crew: 2 Passengers: 3
Injuries:	Nil
Nature of damage:	Minor
Pilot-in-Command:	
Licences:	Airline Transport Pilot Licence (Aeroplane)
Ages:	**a.** 35 years **b.** 41 years
Total flying experience:	**a.** 5 500 hours (400 on type) **b.** 9 700 hours (300 on type)
Investigator in Charge:	R Chippindale

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[1] Aircraft "a"
[2] Aircraft "b"
[3] All times in this report are NZDT (UTC + 13 hours)

1. Factual Information

1.1 On Friday 12 January and Thursday 18 January 1996, Metroliners ZK-POB and ZK-SDA respectively were involved in runway excursions after the pilot flying (PF) engaged the nosewheel steering during the landing run. No injuries were sustained in either event and the damage to each aircraft was minor.

Friday 12 January: ZK-POB

1.2 ZK-POB departed from Auckland at 2215 hours on Thursday 11 January bound for Christchurch as Air Post Flight 21. After an uneventful flight the aircraft was cleared in direct for runway 20 at about 50 miles from Christchurch.

1.3 The approach to runway 20 involved a tailwind of some 15 knots on the approach, reducing to some five knots on touch down. The approach was in IMC until about 600 feet agl on final for runway 20.

1.4 The nosewheel steering was armed during the approach checks and the undercarriage and partial flap lowered by eight miles DME with the landing checks completed apart from the "full flap" item.

1.5 The pilots were aware of the tailwind on the approach. The V_{ref} was 115 knots and the aircraft touched down at V_{ref} with full flap on the wet runway at 0006 hours on 12 January 1996.

1.6 It was not raining when the aircraft landed and the initial roll out was normal and close to the runway centreline. The Co-pilot advised the Captain, who was the PF, that the "Beta" lights were illuminated and called the airspeed as it reduced through 100 knots and then 90 knots.

1.7 As the airspeed reduced through 90 knots the Captain commanded reverse on the engines gently and engaged the nosewheel steering button on the left power lever.

1.8 Immediately after the steering was engaged the aircraft slewed to the right. The Captain responded by releasing the steering and attempting to track the aircraft down the runway by applying left rudder and left wheel brake.

1.9 As this corrective action appeared ineffective to the PF, the nosewheel steering was re-selected by placing the speed levers[4] in low (the alternative method of selecting nosewheel steering). This action caused the aircraft to depart further to the right, and it left the runway coming to rest 116 m from the runway edge facing north-west.

Thursday 18 January: ZK-SDA

1.10 ZK-SDA departed from Hamilton Airport bound for Auckland Airport at 0655 hours on 18 January 1996, as Air New Zealand Link Flight NZ2210. There were three passengers and two crew on board.

1.11 After an uneventful flight the aircraft made a visual approach. There was no wind and the aircraft touched down normally at 0735 hours. Nothing untoward occurred during the initial landing roll and the Co-pilot who was the PF selected the propellers to reverse as the aircraft slowed through 90 knots. The runway was dry and the surface wind calm.

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[4] The "speed lever" controls the engine operating rpm during various stages of the operation to reduce the noise level, enhance fuel economy or operate the engine under minimum load.

1.12 The Co-pilot engaged the nosewheel steering at about 75 knots. As he did so the aircraft veered left and continued to do so despite increasing amounts of opposite rudder and braking.

1.13 The Captain took control of the aircraft from the Co-pilot and endeavoured to stop the aircraft turning by using asymmetric power (with the propellers in reverse pitch) and braking in addition to the nose wheel steering. This was unsuccessful and the aircraft left the runway colliding with a runway light in the process.

Nosewheel steering

1.14 The Metro aircraft's rack and pinion nosewheel steering actuator is electrically controlled and is hydraulically actuated when the undercarriage lever is placed in the "DOWN" position. Steering input signals are generated by deflection of the rudder pedals. The "Normal" maximum steering angle is 10° left and right of centre but this can be increased to 63° by holding the "PARK" button in for several seconds.

1.15 When the "NOSE GEAR STEERING" switch is selected to the "ARMED" position during the Approach Checks electrical power is provided to the nosewheel steering system. The supply of power to the system is confirmed by the illumination of a green "NOSE STEERING" light. Nosewheel steering is engaged either by depressing a button on the left power lever or by placing the right speed lever fully rearward. Either method of selection provides power steering of the nosewheel up to 10° either side of centre in the direction commanded by the position of the rudder pedals. When the system is not engaged the nosewheel is free to castor up to 63° either side of centre.

1.16 While the illumination of the green "NOSE STEERING" light indicates the steering system is armed it is also used to indicate if the nosewheel turns more than 3° beyond the angle selected by the rudder pedals. In such an event the green light flashes.

1.17 The system also incorporates an amber "NOSEWHEEL STEER FAIL" light which illuminates if hydraulic pressure is available to the nosewheel steering when it has not been engaged or armed.

1.18 According to the pilots the "NOSEWHEEL STEER FAIL" light did not illuminate in either of the incidents.

1.19 There is a unit in the nosewheel steering system commonly referred to as the "amplifier". This unit is both an amplifier and a fault protection box. It interprets and amplifies the electrical signals from the potentiometers, operated by the rudder pedals, into signals to drive the steering actuator. It detects any unwanted disagreement between the inputs from the potentiometers and in such an event commands a castoring mode.

1.20 The only limitation for the nosewheel steering system mentioned in the flight manual was:

> NOSEWHEEL STEERING
>
> Takeoff is prohibited when there has been a hydraulic system failure.

1.21 One company's Flight Operations Manual under the heading "Landing" stated:

> At the end of the landing roll, when the aircraft has decelerated to taxi speed and nosewheel steering is engaged, the FP (flying pilot) shall call "SPEEDS LOW"....

1.22 In the course of correspondence with the IIC the manufacturer stated:

> While there is no actual speed limitation on the use of nosewheel steering, we do recommend that on the landing roll, the speed levers not be retarded until reaching taxi speeds...The reason for this is that the turn rate increases as speed increases. In other words, the resultant turn will be more pronounced at higher speeds with a steering command input than with the same amount of input at taxi speeds
>
> ...if the pilot waits until he reaches taxi speed to activate the steering, it is not nearly as sensitive as at higher speeds. The steering may be used at higher speeds, but, ...small steering commands result in larger heading deviations because of the speed.
>
> If the rudder pedals are not centred when the steering is activated, a steering deviation may result. On the other hand, if the rudder pedal position varies more than 3° from the position of the nose wheels, the steering may not engage. (For example in a crosswind landing).

1.23 In February 1992 in a newsletter entitled "Facts" the manufacturer referred to a number of runway excursion incidents being caused by pilots retarding the speed levers to the full aft position before the aircraft decelerated to normal taxi speed. This action actuated the nosewheel steering system before its action was expected by the pilots and caught them unawares.

1.24 The consensus among experienced pilots was that there was no maximum speed for engaging the nosewheel steering system on landing. Each was aware of the need to centralise the rudders before engaging the system, particularly when landing in a cross-wind but each was confident that the "kick" which the aircraft gave as a result of a failure to centralise the rudder pedals was able to be controlled without difficulty.

1.25 The nosewheel steering system amplifiers installed in the aircraft involved were examined by separate overhaul agencies. Each agency advised that the amplifier had been damaged beyond repair but the cause was not determined. The amplifiers were intended to be replaced when necessary on an "on condition" basis.

1.26 On the night before the incident, ZK-SDA had been prepared for the incorporation of a modification to the nosewheel (see paragraph 1.27). A cannon plug in some associated wiring had not been secured correctly after it was found impracticable to install the modification. It could not be determined if the loose plug led to the failure of the amplifier in that aircraft.

1.27 Neither aircraft had incorporated an optional modification (SB 227-32-034) which replaced a wet armature servo valve with a dry armature servo valve and added a by-pass check valve to prevent reverse flow to the servo valve through a return line. Each aircraft was so modified after the incidents. The manufacturer advised that the wet armature valve's internal orifices are sensitive to contamination. "If one orifice is restricted or clogged when hydraulic pressure is applied to the manifold, the steering will activate in the direction opposite to the restricted orifice."

1.28 A review of the maintenance logs on one aircraft showed a short history of complaints relating to a tendency for the aircraft to pull to one side when the nosewheel steering was engaged. Each of the reports on these incidents had resulted in rectification action which appeared to cure the defect.

1.29 The defect report on the amplifier from the same system indicated areas of damaged and burnt components which may have been related to the series of reported defects. Following the replacement of the amplifier and the incorporation of the modification no further problems were experienced.

1.30 Examination of the scene of the incident at Christchurch Airport showed no sign of aquaplaning or skidding of any of the aircraft's tyres. The nosewheel tyres' tracks in particular indicated that the nosewheels were not opposing the direction of the aircraft's travel.

1.31 The manufacturer's Test Pilot observed, in part, that it appeared the 90 knots limitation regarding full reverse application was being misinterpreted as a prohibition of any reverse thrust at speeds in excess of 90 knots. He continued:

> The early application of Beta and/or reverse will significantly shorten the landing distance/braking distance required and enhance the controllability of the aircraft in ground operations by rapidly dissipating kinetic energy during rollout. Additionally it acts to disturb airflow over the wing (from the root to just outboard of the nacelle - a significant portion of the flap span) effectively behaving like ground spoilers/lift dumpers and thereby increasing weight on the wheels improving brake effectiveness and stability.
>
> As the aircraft departed the centre line and NWS appeared insufficient to correct the deviation, forward positive thrust should have been commanded on the engine in the direction of the turn (i.e. right turn - apply increased thrust on the right engine) to overcome the turning tendency. Opposite brake and rudder were proper responses however commanding speeds low would reduce engine thrust/responsiveness and exacerbate the control problem as was evidenced.
>
> Operating this aircraft at high speed (above taxi speed) on the ground with [propeller] speeds low is not recommended.
>
> As far as a maximum or minimum speed to engage NWS I reference it to rudder effectiveness. When rudders are sufficient to control heading during takeoff, I release the NWS power button on the left power lever. Similarly on landing rollout I do not depress the NWS power button on the L.H. power lever until I begin to lose rudder effectiveness. I never rely on the R.H. speed lever microswitch for NWS power except when taxiing.
>
> I do recommend reverse application once all gear are firmly on the landing surface irrespective of speed. I respect the 90 knots limitation regarding full reverse.

2. Analysis

2.1 Each of the two events had distinct similarities namely:

- The nosewheel steering was engaged at a speed in excess of the taxi speed.
- The company did not advise against the use of nosewheel steering above taxi speeds.
- The PF persisted with the use of the nosewheel steering after the fault became apparent.
- The aircraft nosewheel steering system did not have modification (SB 227-32-034) embodied.
- The nosewheel steering system's amplifier was unserviceable.

2.2 The Captain on each aircraft was experienced on the aircraft type. While one was not the PF when the problem became evident he assumed control when the PF encountered the problem.

2.3 Each Captain persisted with the use of the nosewheel steering system after it was evident that it was not performing as expected. While not inviolable it is normal practice, if a new setting of a system results in an unexpected outcome, to return it to the last setting at which the situation was normal and accept that as a limitation until the cause of the malfunction can be investigated.

2.4 On reflection each Captain stated that it was not logical to have persisted with the use of the nosewheel steering system and neither had an explanation for doing so.

2.5 It was apparent that some pilots believed the nosewheel steering system should not be used above taxiing speed while others understood there was no limit. The manufacturer agreed that there was no maximum speed but cautioned that it was more responsive at the higher speeds. In neither of the incidents was the aircraft's speed the basic cause of the runway excursion but it did contribute to the difficulty of regaining control of the aircraft.

2.6 Although the manufacturer has confirmed that there is no maximum speed for the use of the nosewheel steering system it appears that the aircraft can be handled safely at speeds above normal taxiing speed without the benefit of the system. Experienced pilots claimed however that the aircraft is sensitive directionally during the landing run, and that the system assists materially in directional control as the rudder loses its effectiveness. Therefore the use of the system above taxi speeds should not be discontinued arbitrarily.

2.7 The defect in the systems which led to the incidents was not isolated. The system amplifier was damaged beyond economical repair in each case. This damage could have been the result of an improperly secured plug in one case. In the other case the aircraft's nosewheel steering system performed normally after the event throughout rigorous testing before the amplifier was changed. In each case modification SB 227-32-034 was embodied before the aircraft were returned to service so there was a potential for the servo valve replaced by this modification to have contributed to the problem with the system.

2.8 The pilots' delay in application of reverse thrust, or even the selection of ground fine is intentional in some circumstances e.g. a long runway distance to the appropriate taxiway and strong wind conditions. However there appears to be a lack of appreciation of the advantages of the use of reverse thrust early in the landing roll which should be addressed by the manufacturer publishing an amendment to the flight manual or otherwise.

3. Findings

3.1 In neither case was the PF acting contrary to the manufacturer's advice or the operator's practice in engaging the nosewheel steering system during the landing roll at a speed above normal taxiing speed.

3.2 The departures of the aircraft from the runway may have been avoided had the nosewheel steering system been disengaged promptly, and left disengaged, and asymmetric power applied to correct the swing.

3.3 The indication that the nosewheel steering systems' amplifiers were at least partially responsible for the defects could not be confirmed.

3.4 The present policy of replacing the nosewheel steering amplifier on condition may have been a causal factor in the incidents.

3.5 Provided that the pilots are aware the aircraft is more responsive to inputs to the nosewheel steering system at higher speeds, its use at speeds above normal taxiing speed need not be discontinued.

3.6 It would be appropriate for the manufacturer to clarify the benefits of using reverse thrust early in the landing run and to emphasise that partial reverse thrust may be used above 90 knots providing the aircraft's wheels are firmly on the landing surface.

4. Safety Recommendations

4.1 It was recommended to the aircraft manufacturers that they:

> Review the guidance provided for pilots on the control of the Metroliner aircraft during the landing roll (062/96) and;
>
> Review the maintenance procedure to ensure as far as practicable that the amplifier/fault protection unit in the nosewheel steering system is replaced before it fails in service. (063/96)

11 December 1996

M F Dunphy
Chief Commissioner

Glossary of Aviation Abbreviations

AD	Airworthiness Directive
ADF	automatic direction-finding equipment
agl	above ground level
AI	attitude indicator
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
amsl	above mean sea level
AOD	aft of datum
ASI	airspeed indicator
ATA	actual time of arrival
ATC	Air Traffic Control
ATD	actual time of departure
ATPL (A *or* H)	Airline Transport Pilot Licence (Aeroplane *or* Helicopter)
AUW	all-up weight
°C	degrees Celsius
CAA	Civil Aviation Authority
CASO	Civil Aviation Safety Order
CDI	course deviation indicator
CFI	Chief Flying Instructor
C of A	Certificate of Airworthiness
C of G (*or* CG)	centre of gravity
CPL (A *or* H)	Commercial Pilot Licence (Aeroplane *or* Helicopter)
DME	distance measuring equipment
E	east
ELT	emergency location transmitter
ERC	Enroute Chart
ETA	estimated time of arrival
ETD	estimated time of departure
°F	degrees Fahrenheit
FAA	Federal Aviation Administration (United States)
FL	flight level
ft	foot/feet
g	acceleration due to gravity
GPS	Global Positioning System
h	hour
HF	high frequency
hPa	hectopascals
hrs	hours
HSI	horizontal situation indicator
IAS	indicated airspeed
IFR	Instrument Flight Rules
IGE	in ground effect
ILS	instrument landing system
IMC	instrument meteorological conditions

in	inch(es)
ins Hg	inches of mercury
kg	kilogram(s)
kHz	kilohertz
KIAS	knots indicated airspeed
km	kilometre(s)
kt	knot(s)
LAME	Licensed Aircraft Maintenance Engineer
lb	pound(s)
LF	low frequency
LLZ	localiser
Ltd	Limited
m	metre(s)
M	Mach number (e.g. M1.2)
°M	degrees Magnetic
MAANZ	Microlight Aircraft Association of New Zealand
MAP	manifold absolute pressure (measured in inches of mercury)
MAUW	maximum all-up weight
METAR	aviation routine weather report (in aeronautical meteorological code)
MF	medium frequency
MHz	megahertz
mm	millimetre(s)
mph	miles per hour
N	north
NDB	non-directional radio beacon
nm	nautical mile
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board (United States)
NZAACA	New Zealand Amateur Aircraft Constructors Association
NZDT	New Zealand Daylight Time (UTC + 13 hours)
NZGA	New Zealand Gliding Association
NZHGPA	New Zealand Hang Gliding and Paragliding Association
NZMS	New Zealand Mapping Service map series number
NZST	New Zealand Standard Time (UTC + 12 hours)
OGE	out of ground effect
okta	eighths of sky cloud cover (e.g. 4 oktas = 4/8 of cloud cover)
PAR	precision approach radar
PIC	pilot in command
PPL (A *or* H)	Private Pilot Licence (Aeroplane *or* Helicopter)
psi	pounds per square inch
QFE	an altimeter subscale setting to obtain height above aerodrome
QNH	an altimeter subscale setting to obtain elevation above mean sea level
RNZAC	Royal New Zealand Aero Club
RNZAF	Royal New Zealand Air Force
rpm	revolutions per minute
RTF	radio telephone or radio telephony

s	second(s)
S	south
SAR	Search and Rescue
SSR	secondary surveillance radar
°T	degrees true
TACAN	Tactical Air Navigation aid
TAF	aerodrome forecast
TAS	true airspeed
UHF	ultra high frequency
UTC	Coordinated Universal Time
VASIS	visual approach slope indicator system
VFG	Visual Flight Guide
VFR	visual flight rules
VHF	very high frequency
VMC	visual meteorological conditions
VOR	VHF omnidirectional radio range
VORTAC	VOR and TACAN combined
VTC	Visual Terminal Chart
W	west