

FINAL REPORT



SERIOUS INCIDENT 2019/436

State Commission on Aircraft Accidents Investigation (PKBWL)

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FINAL REPORT

SERIOUS INCIDENT

OCCURRENCE NO – 2019/436

AIRCRAFT – BOEING 777-258, 4X-ECC

DATE AND PLACE OF OCCURENCE – 15 February, 2019, EPWA



The Report is a document presenting the position of the State Commission on Aircraft Accidents Investigation concerning circumstances of the air occurrence, its causes and safety recommendations. The Report was drawn up on the basis of information available on the date of its completion.

The investigation may be reopened if new information becomes available or new investigation techniques are applied, which may affect the wording related to the causes, circumstances and safety recommendations contained in the Report.

Investigation into air the occurrence was carried out in accordance with the applicable international, European Union and domestic legal provisions for prevention purposes only. The investigation was carried out without application of the legal evidential procedure, applicable for proceedings of other authorities required to take action in connection with an air occurrence.

The Commission does not apportion blame or liability.

In accordance with Article 5 paragraph 6 of the Regulation (EU) No 996/2010 of the European Parliament and of the Council on the investigation and prevention of accidents and incidents in civil aviation [...] and Article 134 of the Act – Aviation Law, the wording used in this Report may not be considered as an indication of the guilty or responsible for the occurrence. For the above reasons, any use of this Report for any purpose other than air accidents and incidents prevention can lead to wrong conclusions and interpretations

This Report was drawn up in the Polish language. Other language versions may be drawn up for information purposes only.

WARSAW 2022

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Abbreviations

ACTL	Actual
AFT-LMT	Aft Limit
AON	Handling Agent
ARC	Airworthiness Review Certificate
ARST	Aircraft Radio Station License
ATPL(A)	Airline Transport Pilot License (Airplane)
BEW	Basic Empty Weight
CAA	Civil Aviation Authority
CCTV	Closed Circuit Television
CD	Calendar Day
CG	Center of Gravity
CofR	Certificate of Registration
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
CY	Cycle
DOW	Dry Operating Weight
EH	Engine Hour
EPWA	Warsaw Chopin Airport – ICAO Location Indicator
FDR	Flight Data Recorder
FH	Flight Hour
FO	First Officer
FWD-LMT	Forward Limit
GS	Ground Speed
HEAD	Heading
HEAD	Flight with Head of State status

ICAO	International Civil Aviation Organization
IDLE	The lowest speed setting on a running engine (on the ground or in flight)
IIC	Investigator-in-Charge
IOL	Aerodrome manual
kt	knot
LMT	Local Mean Time
LVTO	Low Visibility Take-Off
LW	Landing Weight
MAC	Mean Aerodynamic Chord
MLW	Maximum Landing Mass/Weight
MTOW	Maximum Take-off Weight (Mass)
MTW	Maximum Taxi Weight (Mass)
MZFW	Maximum Zero Fuel Weight (Mass)
N/A	Not applicable
NTSB	National Transportation Safety Board
P/N	Part Number
PIC	Pilot-in-Command
QAR	Quick Access Recorder
QNH	Barometric pressure at nautical height
RPM	Revolutions per minute
RVR	Runway Visual Range
SAC	Standard Airworthiness Certificate
SCAAI/ PKBWL	State Commission on Aircraft Accidents Investigation
TAC	Total Aircraft Cycles
TAH	Total Aircraft Hour
TF	Trip Fuel
TOF	Take-Off Fuel

TOMAC	Take-Off MAC
TOW	Take-off Weight (Mass)
TSN	Time Since New
TWR	Aerodrome control tower
TWY	Taxiway
ULC	Civil Aviation Authority of the Republic of Poland
UNDL	Remaining underload
UTC	Universal Time Coordinated
VIP	Very Important Person
ZFMAC	Zero Fuel MAC
ZFW	Zero Fuel Weight (Mass)

General Information

Occurrence reference number:	2019/436			
Type of occurrence:	SERIOUS INCIDENT			
Date of occurrence:	15 February, 2019			
Place of occurrence:	EPWA			
Type and model of aircraft:	BOEING 777-258			
Aircraft registration marks:	4X-ECC			
Aircraft user/operator:	EL AL ISRAEL AIRLINES LTD.			
Aircraft Commander:	ATPL(A)			
Number of victims/injuries:	Fatal	Serious	Minor	None
	0	0	0	105
Domestic and international authorities informed about the occurrence:	<ul style="list-style-type: none"> – ULC, ICAO, EASA, European Commission – NTSB, Chief Investigator Aviation Incidents & Accidents Investigation Ministry of Transport State of Israel 			
Investigator-in-charge:	Andrzej Bartosiewicz			
Investigating authority:	State Commission of Aircraft Accidents Investigation (PKBWL)			
Accredited Representatives and their advisers:	Not appointed			
Document containing results:	FINAL REPORT			
Safety recommendations:	NONE			
Addressees of the recommendations:	Not applicable			
Date of completion of the investigation:	23 August, 2022			

Synopsis

On 14 February, 2019, a HEAD status flight of the Boeing 777-258 (with 4X-ECC registration marks) was planned on the Warsaw (EPWA) – Tel Aviv (LLBG) route. The plane was scheduled to take off at 23 hrs LMT¹. The final preparation of the aircraft for the flight took place on the BRAWO apron located on the military part of the EPWA airport.

The crew arrived on scheduled time. Prior to boarding, the Captain agreed with the headset operator that the aircraft engines would be started during the pushback-towing operation. The route of the plane's push-back and towing was agreed among the headset operator, the towing tractor operator and the military coordinator of ground movement.

The passengers arrived with a delay and at around 23:55, they began boarding.

During push-back, the crew started up the right engine. After several dozen seconds, the push-back was completed and the towing started.

The SCHOPF F210 towing tractor and universal J-TOWversa1-A towbar were used for push-back and towing.

During the towing, prior to the right turn beginning, the right engine start-up was complete – the engine has reached the IDLE RPM. After a few seconds, during the right turn, the crew commenced the start-up process of the left engine. Moments later, in the mid phase of the turn, the left pin of the towbar was sheared off. In the end phase of the turn, the left engine start up process was completed – the engine reached the IDLE RPM. When both engines were on IDLE, the plane began to push the tractor and the tractor-plane combination increased the speed to 3 kt. A few seconds later the towbar folded, its right shear pin and retaining bolt were sheared off, which was followed by a collision of the plane with the tractor.

No person was injured as a result of the incident. The aircraft, tractor and towbar were damaged.

The investigation was conducted by the PKBWL Investigation Team in the following composition:

Andrzej Bartosiewicz	Investigator-in-Charge;
Krzysztof Błasiak	Team Member;
Krzysztof Miłkowski	Team Member;
Bogusław Trela	Team Member.

¹ All times throughout the Report are in LMT, unless otherwise indicated. On the day of the occurrence LMT=UTC+1h

Cause of the occurrence:

The direct cause of the serious incident was lack of reaction to the shearing of the towbar pin and the continuation of the aircraft towing.

Contributing factors:

- 1) Start-up of both engines during pushback-towing operation.
- 2) Setting of the towbar pins not compatible with the type of aircraft which was pushed-back and towed.
- 3) Fatigue of the ground handling staff caused by extended hours of work at night in adverse weather conditions.
- 4) Stress of ground handling staff due to servicing the HEAD status flight and procedures imposed by the operator.

PKBWL has not proposed safety recommendations after the investigation.

1. FACTUAL INFORMATION

1.1. History of the flight

On 14 February 2019, at 23:00 hrs, the Boeing 777-258 flight with 4X-ECC registration marks on the EPWA – LLBG route was scheduled. It was a HEAD status flight.

Final preparation of the plane for the flight was carried out in front of the VIP terminal on the military apron of EPWA aerodrome (Fig. 1).

The crew arrived at the apron at the scheduled time (around 20:30 hrs) and performed standard pre-flight procedures. Before boarding the aircraft, the Captain agreed with the headset operator that both engines would be started during the pushback-towing operation.

Passengers for the flight arrived late and at 22:55 began boarding.

Before the start of the push-back, the headset operator, the tractor operator and the military ground movement coordinator agreed that the plane would be pushed back, and then towed with a right turn and lined up facing the entrance of the TWY Z3 of EPWA aerodrome.



Fig. 1. Boeing B777-258, accident aircraft before push-back [source: CCTV camera of VIP terminal on EPWA aerodrome]². Note: The date and time in the lower right corner are in the LMT.

The push-back of the aircraft began as planned. After moving several dozen metres straight, the crew commenced the right engine start up process.

The sequence of push-back and towing as well as the time of the occurrence are shown below on the individual frames from the CCTV camera recording (Fig. 1).

² Unless otherwise indicated – [source: PKBWL]



Fig. 1. Boeing B777-258, accident aircraft, during push-back and towing: A – push-back initiation; B – right engine start-up initiation; C – end of push-back; D – towing initiation; E – end of right engine start-up; F – left engine start-up initiation; G – shearing the left pin of the towbar; H – end of left engine start-up; I – tractor being pushed by the aircraft; J – collision (aircraft and tractor stopped)

After push-back and stopping the tractor-aircraft combination, the operator of the tractor started towing the aircraft at the speed of GS=1 kt.

In the initial phase of towing (before the right turn), the right engine start-up process was completed and its RPM reached N1=18.5%. Further towing was continued along a small radius arc with a 96° turn to the right.

When the tractor turned right, and the plane was still moving straight, the flight crew commenced the start-up process of the left engine. About 2-3 seconds later, the left (external in relation to the turn direction) towbar pin was sheared off.

At the end of the turn, the RPM of the left engine reached N1=18.5%. Eight seconds later, the tractor-aircraft combination accelerated to GS=2 kt, and after next 2 s it slowed down to the initial speed of GS=1 kt. A moment later the towing tractor operator started a right turn towards TWY Z3 of EPWA aerodrome, but the aircraft continued to move straight, accelerating to 3 kt. At this point, the towbar folded and its right shear pin and retaining bolt were sheared off, which caused that the aircraft-tractor connection lost its stiffness, and the separation of the aircraft from the tractor was no longer possible. The plane began to overtake the tractor, as a result the tractor got under its fuselage and, as a consequence a collision occurred. At this point, the towing operation was aborted.

The towing tractor operator's cabin was raised during the towing operation, which resulted in damage to the lower nose part of the fuselage.

The proper tractor, towing bar and appropriate shear pins in the towbar were used for towing, however, the setting of the pins was inconsistent with the requirements indicated in the towbar operating manual relative to the type of the aircraft.

As a result of the occurrence, the plane was damaged and required a repair which prevented the planned flight. In addition, the towbar, towing tractor and the surface of the apron were also damaged.

1.2. Injuries to persons

Injuries	Crew	Passengers	Others	Total
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	2/11	90	2	105

1.3. Damage to aircraft

The damage to the accident aircraft was limited to the two zones marked in the figure below.

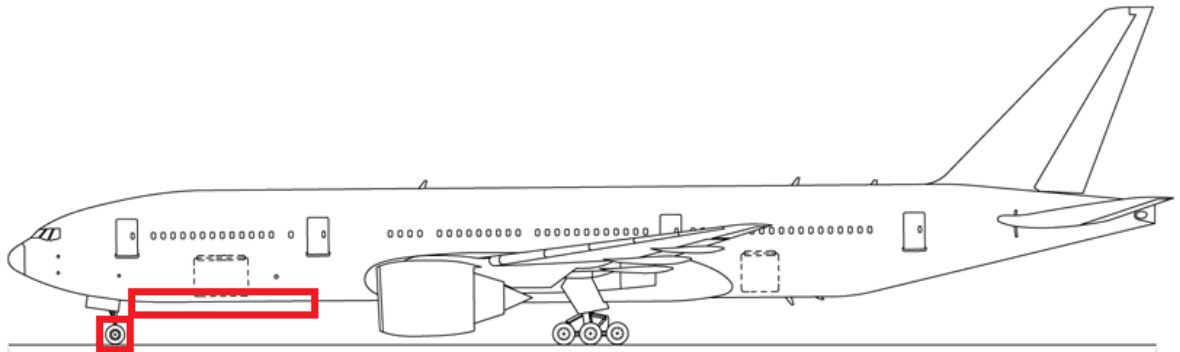


Fig. 2. Damage areas of the accident aircraft marked as red boxes.

The accident aircraft sustained the following damage (see the photos illustrating the damage in the Album of Illustrations):

- numerous dents and multiple tears in the skin of the fuselage that were a result of the collision with elements of the towing tractor’s roof, resulting in loss of pressurization of the fuselage in the baggage compartment area;
- numerous scratches on the lower part of the fuselage skin that were a result of collision with elements of the towing tractor’s roof;
- abrasions on the rim edges of the front landing gear that were caused by its contact with the towing tractor;
- multiple abrasions of the tire of the right front landing gear wheel caused by its contact with the towing tractor.

The aircraft was damaged to a degree that required a repair.



Fig. 3. B777-258, accident aircraft during repair at EPWA aerodrome – damage view

1.4. Other damage

1.4.1. Towbar damage

J-TOWversa1-A towbar, serial number: J1001619 sustained the damage described below (see the Album of Illustrations for detailed photos of the damage):

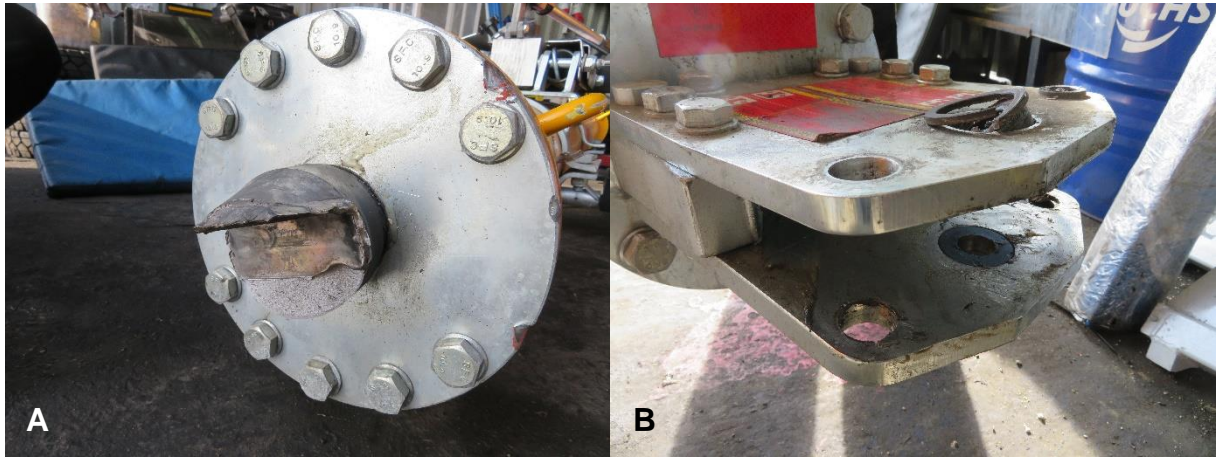


Fig. 4. J-TOWversa1-A towbar: A – damaged towing eye, B – damaged towhead

- 1) Breakage of the welds of the fitting connecting the towing eye with the tractor, which resulted in the separation of the fitting from the towbar. The fitting remained connected with the tractor after the occurrence.
- 2) The flanged fastening of the drawbar ferrule on the tractor side was locally deformed in three places.
- 3) The fastening of the towhead from the side of the aircraft was damaged by:
 - multi-plane brittle fracture of the retaining bolt of the towhead mounting;
 - multi-plane, brittle fracture of both shear pins of the towhead mounting;
 - partial deformation and tearing out of parts of the upper and lower sleeves fixing the position of the retaining bolt and pins in the towhead mounting ferrule;
 - one-sided deformation of the central part of the towhead mounting ferrule (an element distancing the upper and lower metal sheets of the ferrule);
 - plastic deformation (bending) of the upper and lower metal sheet of the towing drawbar towhead mounting ferrule;
 - local deformations of the metal sheet surface of the towhead mounting ferrule caused by fragmented pins and sleeves fixing the position of the pins in the ferrule.
- 4) The J-TOWversa1-A towhead was damaged as described below:
 - deformation of the bushings seats fixing the position of the retaining bolt and shear pins in the towhead;
 - destruction of the rubber sleeve fixing the position of the retaining bolt in the towhead;

- shearing off the two of four screws fixing the towhead in relative to the landing gear strut.
- 5) The collision of the aircraft and towing tractor damaged the coating of the towbar and caused slight scratches.

The sheared off fragments of the left pin of the towbar were found on the apron. The location is shown below (Fig. 5).



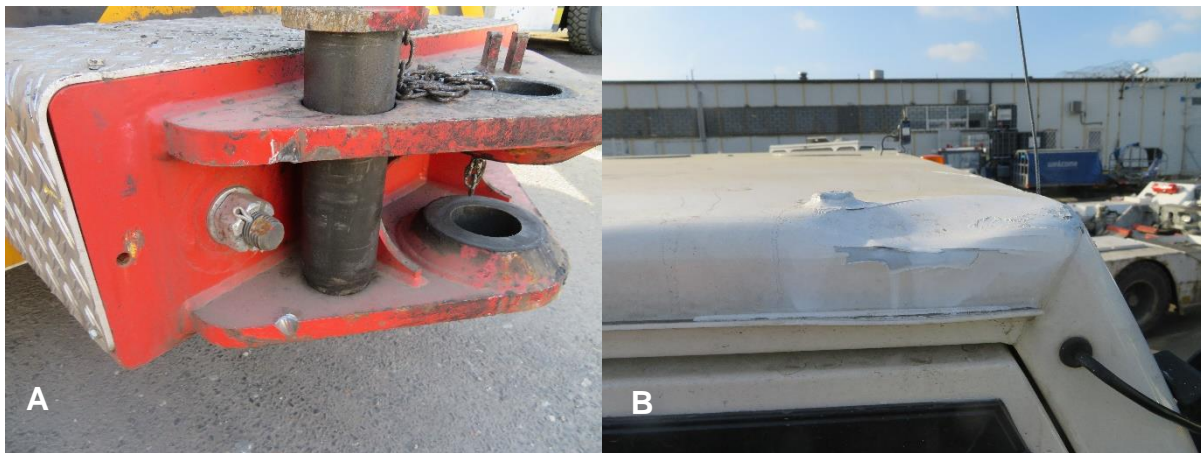
Fig. 5. EPWA aerodrome apron – the arrows show the fragments of the left shear pin (relative to the direction of the tractor-aircraft combination movement)

1.4.2. Towing tractor damage

The J-SCHOPF F210 towing tractor (serial number:1223) involved in the occurrence, sustained the damage described below (see the Album of Illustrations for detailed photos of the damage):

- radio antenna mounted on the roof – bent but working properly after straightening its mounting;
- two bolts torn out of the tractor roof – one of the pins got stuck in the damaged skin of the aircraft fuselage, while the other was found on the apron after the occurrence;
- slight, plastic deformation of the edges of the tractor front fittings used for mounting the towbar;
- abrasion of the right corner of the towing tractor front bumper;
- dent in the area of the right front part of the towing tractor operator cabin;

- minor paint abrasions on the right side of the towing tractor (side, rear right wheel arch), caused by the contact of the towing tractor with a broken towbar and the front landing gear of the accident aircraft.



Rys. 6. J-SCHOPF F210 towing tractor: A – coupling damage, B – roof damage

1.5. Personnel information (crew data)

1.5.1. Captain

Pilot – male, aged 58

Holder of ATPL(A)

Ratings – MEP(L) – B-757/767, B-737-300-900, B-777-200

Aero-medical certificate – valid until: 11 August 2019

Simulator training – 24 August 2018

Language proficiency – English, ICAO level 6

Flight time as captain on types:

- B 757 – 588 h;
- B 737 – 813 h;
- B 777 – 799 h.

1.5.2. First officer

Pilot – male, aged 51

Holder of ATPL(A)

Ratings – MEP(L) – B-767, B-777-200

Aero-medical certificate – valid until: 27 July 2019

Simulator training – 22 October 2018

Language proficiency – English, ICAO level 6

Flight time on types:

- B 767 – 1 216 h;
- B 777 – 98 h.

1.6. Aircraft information

1.6.1. General information

Aircraft:

- aircraft class – airplane;
- subcategory – large transport airplane³;
- construction – wide-fuselage low-wing metal composite airplane;
- manufacturer – The Boeing Company;
- manufacturer's designation – BOEING 777-258 (B777-200ER);
- serial number – 30833;
- aircraft owner – EL-AL Israel Airlines Ltd.;
- aircraft operator – EL-AL Israel Airlines Ltd.;
- engine type – turbofan;
- number, manufacturer, engine type and model – 2 x Rolls-Royce RB211 Trent, 895-17⁴ model;
- landing gear – three-cycle, retractable, with dual-wheel on the nose landing gear strut and six-wheel truck on the main landing gear struts.

Certificate of Registration (CofR) – valid on the day of occurrence:

- registration marks – 4X-ECC;
- issue date – 11 April 2001.

Standard Airworthiness Certificate (SAC) – valid on the day of occurrence:

- issue date – 11 April 2018;
- valid until – 10 April 2019.

Aircraft Radio Station License (ARSL) – valid on the day of occurrence:

- issue date – 3 December 2018;
- valid until – 1 December 2020.

Aircraft dimensions:

- length – 63,7 m;
- wingspan – 60,9 m;
- height – 18,4 m;
- wing area – 427,8 m².

Aircraft mass:

- MTW 298 463 kg;
- MTOW 297 556 kg;
- MLW 213 188 kg;
- MZFW 200 487 kg.

³ The world's largest dual-engine airplane.

⁴ The most powerful version of the Trent 800 engine family.



Fig. 7. Boeing 777-200ER, 4X-ECC, accident aircraft [source: Wikimedia.org]

1.6.2. Service life data⁵

AIRFRAME – Boeing 777-258

Year of Manufacture:	2001
TAH:	72 785
TAC:	8 490
Date of the last periodic check:	01.10.2018

ENGINE 1 (LEFT) – Trent 895-17

Date of installation on airframe:	24.12.2017
Serial number:	51 281
TSN:	58 779
CSN:	6 898

SILNIK 2 (PRAWY) – Trent 895-17

Date of installation on airframe:	02.03.2017
Serial number:	51521
TSN:	33 742
CSN:	3 830

1.6.3. Mass and balance of aircraft

According to the final loading and balance sheet of the aircraft, the mass and balance data were as follows:

- ZFW – 157 482 kg;

⁵ Data from 1 August, 2018.

- MZFW – 199 580 kg;
- TOF – 32 300 kg;
- TF – 18 981 kg;
- TOW – 189 782 kg;
- MTOW – 285 499 kg;
- LW – 170 801 kg;
- MLW – 213 188 kg;
- UNDL – 42 098 kg;
- BEW – 140 175 kg;
- DOW – 146 859 kg;

	FWD-LMT	ACTL	AFT-LMT
TOMAC	8,19	19,3	30,15
ZFMAC	7,98	16,7	29,11

The mass and balance of the aircraft were within the prescribed limits.

1.7. Meteorological information

Weather conditions, according to the METAR for EPWA on 15 February, 2019 at 00:00 hrs, were as follows:

EPWA 150000Z 0000KT 6000 BKN018 05/05 Q1033 TEMPO 4000 BR BKN012

- date: 15.02.2019 r.;
- hour: 00:00;
- wind direction: windless;
- wind speed: windless;
- visibility: 6 000 m;
- cloud amount: from 5/8 to 7/8, cloud base: 1 800 ft AGL;
- temperature: 5°C;
- dew point temperature: 5°C;
- pressure: QNH 1033 hPa;
- TREND forecast: within an hour visibility decreased to 4,000m in fog, cloud amount – broken, cloud base lower to 1,200 ft AGL.

1.8. Aids to navigation

Not applicable

1.9. Communications

The crew maintained standard radio communication with EPWA TWR in English. Communication in both directions was readable.

The crew communicated by wire with the operation coordinator. Neither side reported any communication issues. Commands were given in English. Because CVR records have been overwritten, PKBWL did not have access to the communication recording.

1.10. Aerodrome information

Warsaw Chopin Airport is approved and prepared to handle all aircraft up to the reference code 4E. The airport management allows the operations of aircraft with a higher code letter (B-748, A-380, C-5B Galaxy, An-124) in accordance with the procedure described in the Airport Operations Manual (AOM). Permitted air traffic: IFR / VFR, possible operations according to ILS categories I, II and III and LVTO at RVR not less than 125 m. Allowed take-offs from intermediate distances, in accordance with the published distances declared in AIP Poland and AOM.

There are restrictions on air operations at Warsaw Chopin Airport. From 21:00 hrs to 05:00 hrs UTC air operations are allowed only by noise-certified aircraft in accordance with chapters 3, 4, 5 and 10 of Annex 16, Volume I. Restrictions in the abovementioned hours do not apply to state aviation, emergency landings and humanitarian flights. Apron management service – provided by the airport operator. Aerodrome category for fire protection – ICAO CAT 9.

Military unit implements the requirements specified in the Airport Operations Manual. The apron in front of the VIP terminal on the military part of EPWA aerodrome does not have taxi/towing lines marked.

**AERODROME GROUND MOVEMENT CHART
TAXIWAYS FOR A380-800/GP, AN-124-100,
B747-8, C-5B GALAXY**

52°09'57" N
020°58'02" E ELEV 362 ft

Okres: TOWER 118,300
Okres: GROUND 121,900

WARSAW CHOPIN AIRPORT

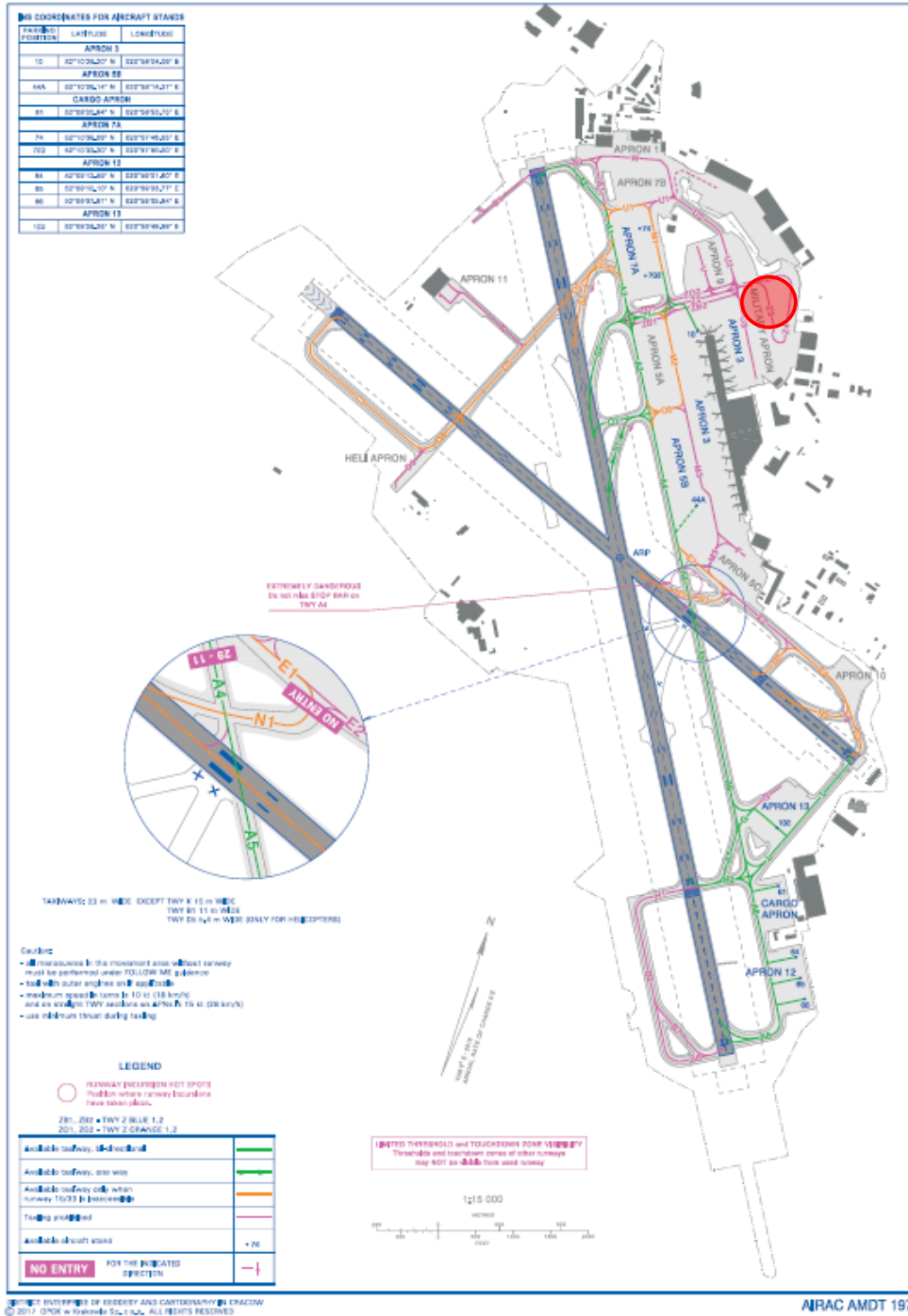


Fig. 8. Ground movement map of the Warsaw Chopin Airport – the red circle indicates the location of the occurrence place [source: AIP Poland]

1.11. Flight recorders

The aircraft involved in the occurrence was equipped with FDR, CVR and QAR.

On the day of the occurrence, in the presence of PKBWL members, the Honeywell P/N 980-4700-042 SSFDR, was removed from the aircraft and secured for readout. The recorder showed no external signs of damage. The data were downloaded from the recorder solid-state memory on February 15, 2019 at the headquarters of the PKBWL in Warsaw. The recorded parameters covered the period of the last 25 hours. The acquired data were used to recreate the course of the occurrence and its analysis. The Insight Analysis 4.9 program by Plane Sciences was used to analyse the parameters.

On the day of the occurrence, in the presence of PKBWL members, the L-3 SSCVR model FA 2100, P / N 2100-1025-22, S / N 001037561 was removed from the aircraft. After the occurrence, the on-board voltage remained on, and the crew did not pull out the recorder circuit breaker, so the recording related to the occurrence was overwritten.

Failure to deactivate the CVR was inconsistent with both the operator's procedures and ICAO recommendations.

The QAR was not made available to the Investigation Team, with explanation that the aircraft was not equipped with this type of recorder.

However, a few days later the operator provided data from QAR in the Excel file format.

1.12. Wreckage and impact information

The occurrence site was shown in the section 1.10, Fig. 8, the placement of the aircraft-tractor combination is shown in Fig. 9 below.

Circumstances of the collision were described in the section 1.1.

The site of the serious incident is shown below (Fig. 10). It presents the marks of the aircraft tires on the apron showing the radius of the turn and the last portion of the travel of the nose landing gear wheels prior to the collision with the towing tractor.



Fig. 9. Occurrence site: A – general view showing the positions of the aircraft, towbar and the tractor after the occurrence; B – collision of the nose landing gear with the tractor



Fig. 10. EPWA apron: A – marks of the right truck of the main landing gear wheels;
B – marks of the front landing gear wheels

1.13. Medical and pathological information

1.13.1. Flight crew

No physiological factors were found that may have affected the performance of the flight crew members.

1.13.2. Ground handling personnel

The towing tractor operator and coordinator involved in the occurrence started their work at 13:00 hrs and 12:30 hrs respectively).

The occurrence took place in the twelfth hour of work of both employees. Adverse weather conditions prevailed at the time of the occurrence and in the preceding hours – it was dark, cold and wet.

Due to security procedures of EL-AL operator, the ground personnel designated and approved by the operator for servicing that flight could not have been replaced, what in combination with long-term work and unfavourable weather conditions, had a negative impact on their perception and efficiency.

The ground personnel were also exposed to psychological factors influencing their activities, such as:

- stress related to completing a new task – the operation coordinator coordinated an operation on the military apron for the first time;
- during preparation of the plane for the flight there was a stressful situation (misunderstanding) between the EL AL mechanics and the ground personnel (EL-AL mechanics performed a cold start of both engines without informing AON employees who are beside the plane);
- stress related to the presence of the operator security services during flight preparation;
- stress and pressure related to servicing the flight with HEAD status.

1.14. Fire

Not occurred

1.15. Survival aspects

Nobody was injured during the occurrence.

It was not necessary to evacuate the passengers. The passengers and crew left the aircraft via passenger stairs.

1.16. Tests and research

Tests and specialist research were not performed.

1.17. Organizational and management information

The push-back and towing of the aircraft was carried out in accordance with Aerodrome manual by a certified ground handling agent with the assistance of a Follow Me with the permission airport duty officer and clearance from TWR.

The push-back and towing procedures on EPWA aerodrome are described in the following documents:

- Warsaw Chopin Airport Operating Manual (IOL-EPWA);
- Assistance of Engine Start-up and Aircraft Push-back/Towing Manual (IR-15);
- Aircraft Push-back and Towing Manual (IR-16);
- Aircraft Service Procedures (welGOM 4).

Aircraft push-back/towing procedures described in IOL-EPWA (selected provisions):

- *The aircraft can be towed on taxiways, runways and through stands in accordance with the road marking and the EPWA TWR clearance;*
- *If there is a necessity to tow the aircraft through the area separated from the aircraft traffic or the aircraft stand from the side where the markings do not allow it, the permission of the airport duty officer and clearance from TWR are required. In this case, towing must be performed with the assistance of a Follow Me or Ground Handling Agent employees;*
- *It is allowed to tow and push-back the aircraft only with the use of certified by the manufacturer equipment, considering the MTOW and type of the aircraft;*
- *The towbar must have a valid review certificate in accordance with the manufacturer recommendations and the ground handling agent instructions (performed at least every 3 months). Before towing, the person responsible for the operation is obliged to check to towbar review validity and its efficiency (including shear pins);*
- *Towing and pushback operation may only be performed by authorized and properly trained ground handling agent personnel. Towing is*

forbidden unless the flight deck crew or ground handling agent personnel (flight mechanic) are in the cockpit;

- *The Ground Handling Agent personnel is responsible for the safe course of the aircraft towing and push-back process. Breach of the rules described in this procedure is treated as a grade III-V offense described in the offense card.*

Aircraft push-back and towing in accordance to welGOM4 (selected provisions):

- *Equipment used to push-back the aircraft must be selected in accordance with the size and weight of the aircraft, the prevailing weather conditions and the condition of the surface;*
- *Towing tractors used for push-back must meet requirements of AHM 955 for all weather conditions, in particular:*

Cat. 1 – aircraft mass below 50.000 kg (tractor weight below 4.000 kg);

Cat. 2 – aircraft mass below 150.000 kg (tractor weight below 12.000kg);

Cat. 3 – aircraft mass below 260.000 kg (tractor weight below 18.000 kg);

Cat. 4 – aircraft mass below 400.000 kg (tractor weight: 40.000 kg and four-wheel drive);

Kat. 5 – aircraft mass above 400.000 kg (tractor weight 60.000 kg and four-wheel drive);

- ***If the aircraft is to be towed after the end of push-back and engine start, special precautions must be taken to reduce the risk of damaging the front landing gear strut or towbar/towing tractor, which may be caused by engine thrust.***
- *The person responsible for the push-back operation is the person having communication with the cockpit during push-back. Each push-back operation must be supervised by a properly trained and dedicated employee.*
- *The responsible person must:*
 - *Provide equipment corresponding with the type of aircraft pushed-back;*
 - *Supervise the entire push-back operation from the moment when a crew approves its initiation;*
 - *Make sure that the towbar / tow eye / tractor are adequate for the aircraft type;*
 - *Conduct a briefing with the personnel involved in the operation to discuss the responsibilities of each individual and agree on how to manoeuvre the aircraft;*

- *Stay in continuous communication with the crew in the cockpit via the headset;*
- *Verify push-back procedures based on new conditions or circumstances and keep the cockpit crew informed about them;*
- *If the apron conditions are different from those for the standard push-back operation, then: inform the cockpit crew that they are not allowed to start the engines until the airplane is in a place on the runway, where conditions are safe enough to start the engines;*
- *Listen to the headset during push-back and communicate with the cockpit when necessary;*
- *Warn the cockpit crew if it is not safe to start the engines and make sure the engine star-up procedure is stopped.*

The operation coordinator was in continuous communication with the flight crew via headset. Due to the overwriting of the CVR recording, the Investigation Team was not able to verify the quality and content of the communication.

1.18. Additional information

1.18.1. Towbar

Date of manufacture: January 2019

Length: 4140 mm

Width: 825 mm

Mass: 354 kg

Review valid until: 28 February, 2019

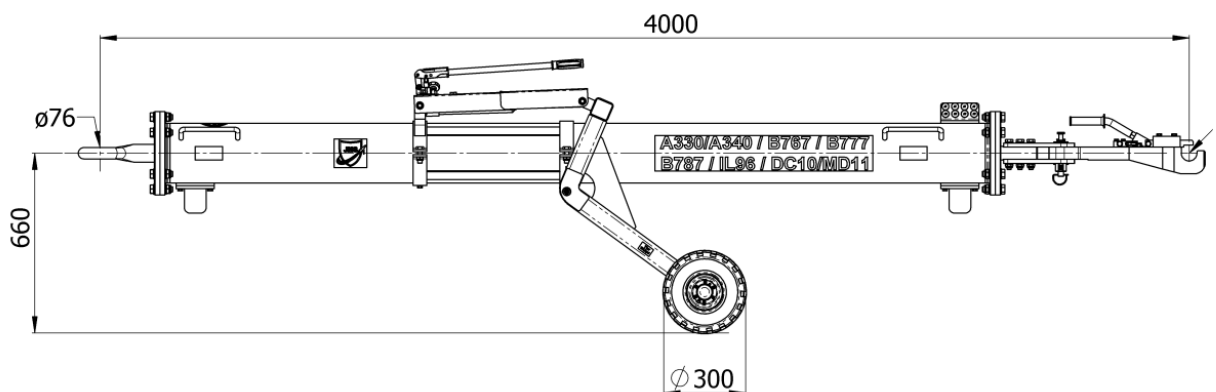


Fig. 11. J-TOWversa1-A towbar scheme [source: <https://jms.aero>]

J-TOWversa1-A towbar is manufactured by the German company „Jet Maintenance & Service” as a configurable towbar for towing and pushing aircraft of the following types:

- A330-200(F)/-300/-800/-900;
- A340-200/-300*1;

- A350-900/-1000;
- B767-200/-300/-400;
- **B777-200/-300**;
- B787-8/-9/-10;
- IL96;
- DC10 *2;
- MD11 *2;
- L1011.

The tow-body is made in the form of a steel tube, supported on a single-axle fixed undercarriage with two pneumatic wheels. The towbar on the tractor's side has a tow-eye to attach the tow-body to the tractor with a pin. From the side of the aircraft, the towbar is equipped with a towhead for connection with the nose landing gear strut. The towhead is attached to the tow-body by inserting its end between the plates and preventing its movement by means of a retaining bolt and two pins with their axes in one plane, perpendicular the main axis of the towbar. The retaining bolt) has a diameter of approximately 23 mm. This bolt is additionally surrounded by a flexible element in the form of a rubber sleeve. After installation, the retaining bolt is secured with a self-locking nut and it is not intended to be serviced during the preparation of the drawbar for operation.

The outer pins, connecting both parts of the towhead are replaceable shear pins, which are to be sheared when excessive force is exerted. In accordance with the towbar manual, the replacement of the pins is done without any tools and is a part of the preparation of the towbar for push-back/towing of a particular type of aircraft. The following pins are standard equipment of the towbar:

- 2 pins marked as „AT”,
- 4 pins marked as „AU”.

Each pin has a convenient handle on the top, for its easy replacement or change of its setting. At the top of the handle, the pins are marked with the letters “AT” or “AU”. According to the manufacturer instruction, each pin can be set in two positions: top and bottom. The selection of a pin and its setting depends on the type of aircraft that can be towed/pushed back with the J-TOWversa1-A.

The pins may take the following positions dependent on the aircraft type:

1. For the „AT” pin:
 - a) bottom position for the following aircraft types:
 - A330 / 340 -200/-300;
 - B767;
 - A350-900 / -1000;
 - IL96, DC10, MD11, L1011;
 - b) top position for the following aircraft type:
 - **B777**.

2. For the „AU” pin:
 - a) bottom position for the following aircraft type:
 - B787-8;
 - a) top position for the following aircraft type:
 - B787-9.

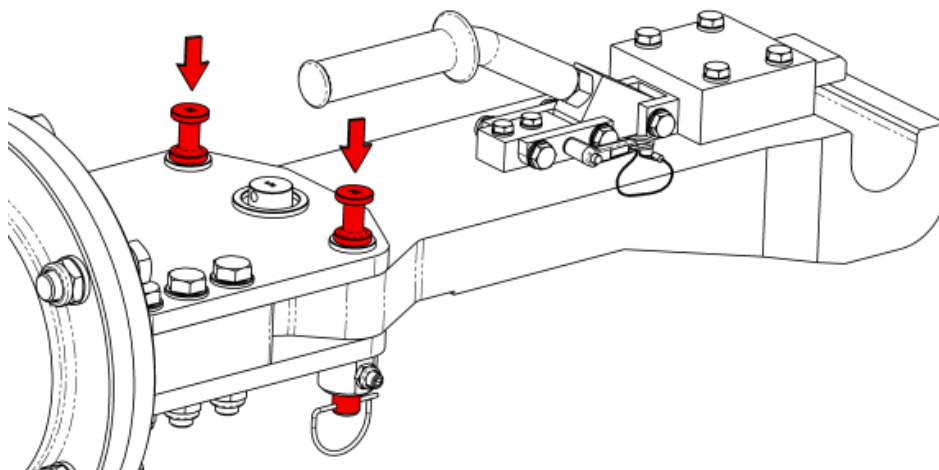
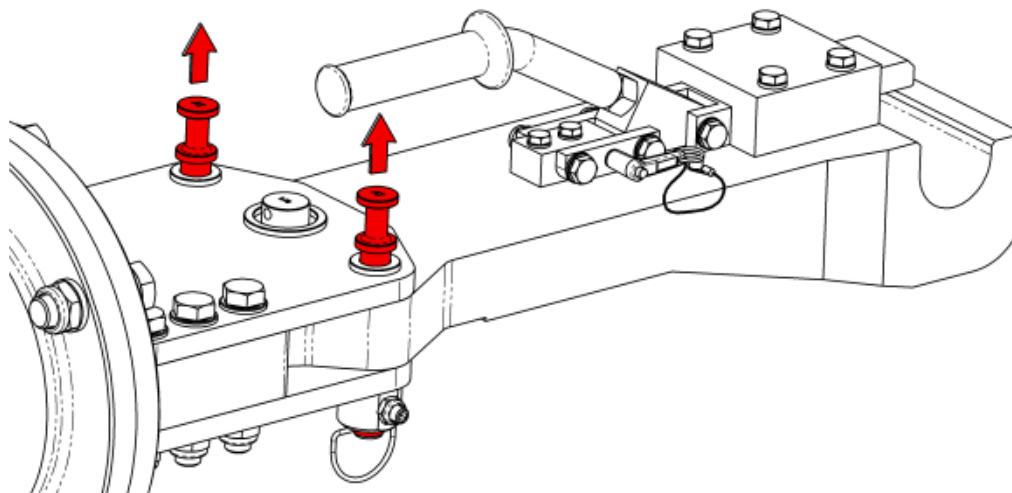


Fig. 12. Bottom position of a pin in the J-TOWversa1-A towhead [source: <https://jms.aero>]



Rys. 13. Top position of a pin in the J-TOWversa1-A towhead [source: <https://jms.aero>]

Information regarding the pins marking and setting was clearly printed on the towbar (Fig. 14-A). The markings of the pins used in the investigated case were in accordance with the manual (Fig. 14-B).

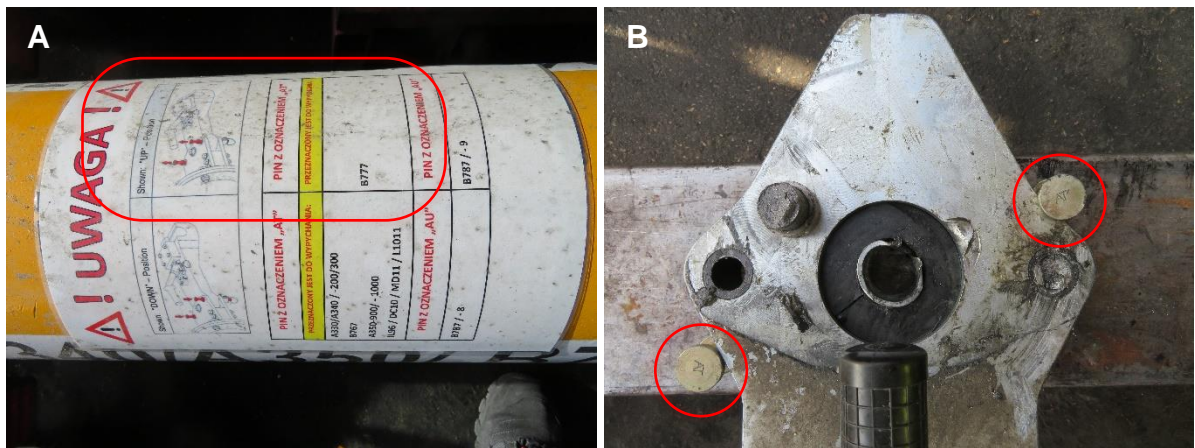


Fig. 14. J-TOWversa1-A towbar: A – type and positioning of pins information; B – sheared pins with visible markings

1.18.2. Towing tractor

Type: SCHOPF F210

Manufacturer: SCHOPF Maschinenbau GmbH

Tractor number: 1223

Length: 6 435 mm

Width: 2 445 mm

Mass: from 22 to 32 t – at the time of the occurrence 30 t

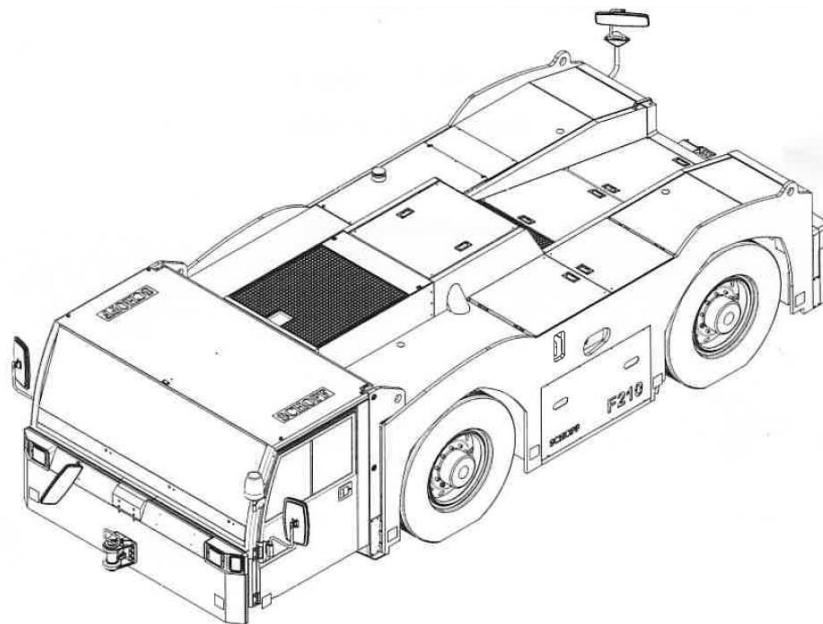


Fig. 15. SCHOPF F210 towing tractor – general view [source: F210 operating manual]

According to the manufacturer, the SCHOPF F210 towing tractor is dedicated to the effective handling of aircraft with a total mass of up to 280 tons, such as Airbus A350 or Boeing 787. The tractor has all-wheel drive and steering systems. Depending on the selected configuration, the tractor has an operation weight of 22,000 / 26,000 / 30,000 / 32,000 kg. The tractor is equipped with a three-circuit hydraulic brake system, in which two hydraulic circuits act as a service brake, while the third hydraulic circuit

serves as an emergency and parking brake. This type of braking system solution ensures its high efficiency and reliability.

1.18.3. Consultation of the draft final report

Before publication of the Final Report, SCAAI solicited comments from the entities and authorities concerned, including EASA.

WELCOME Airport Services Sp. z o. o. – the ground handling agent directly involved in the incident. The entity submitted a total of 11 comments. Two comments on the Commission's findings and the note on safety recommendations were rejected, the remaining comments were included in the final report.

Ministry of Transport Chief Investigator – the authority that investigates air accidents in Israel (representing the state of registration and the state of the operator). The entity submitted a total of 4 comments. Three comments – were included in the text of the final report, and one were rejected.

National Transportation Safety Board – the authority that investigates aviation accidents in the USA (representing the state of design and the aircraft manufacturer) – did not submit any comments.

EASA – did not submit any comments.

1.19. Useful or effective investigation techniques

Standard investigation techniques were applied.

2. ANALYSIS

2.1. Pushback and towing of aircraft

Fig. 16 shows selected parameters of the airplane during push-back and towing, obtained from the FDR recording. The revolutions of the left and right engine compressors (N1, N2 and N3) (left – red, right – green) show the course of their start-up. The red vertical line shows the beginning of the left-hand engine start-up, and the dark blue line shows the time of the tractor-airplane collision. The horizontal orange line shows the release of the airplane parking brake, the brown line shows the speed during push-back/towing, and the purple line shows the change of the magnetic heading.

The figure below clearly shows that both engines reached the IDLE RPM during push-back/towing operation. A while before the collision, the tractor-aircraft combination accelerated from 2 to 3 kt, then stopped.

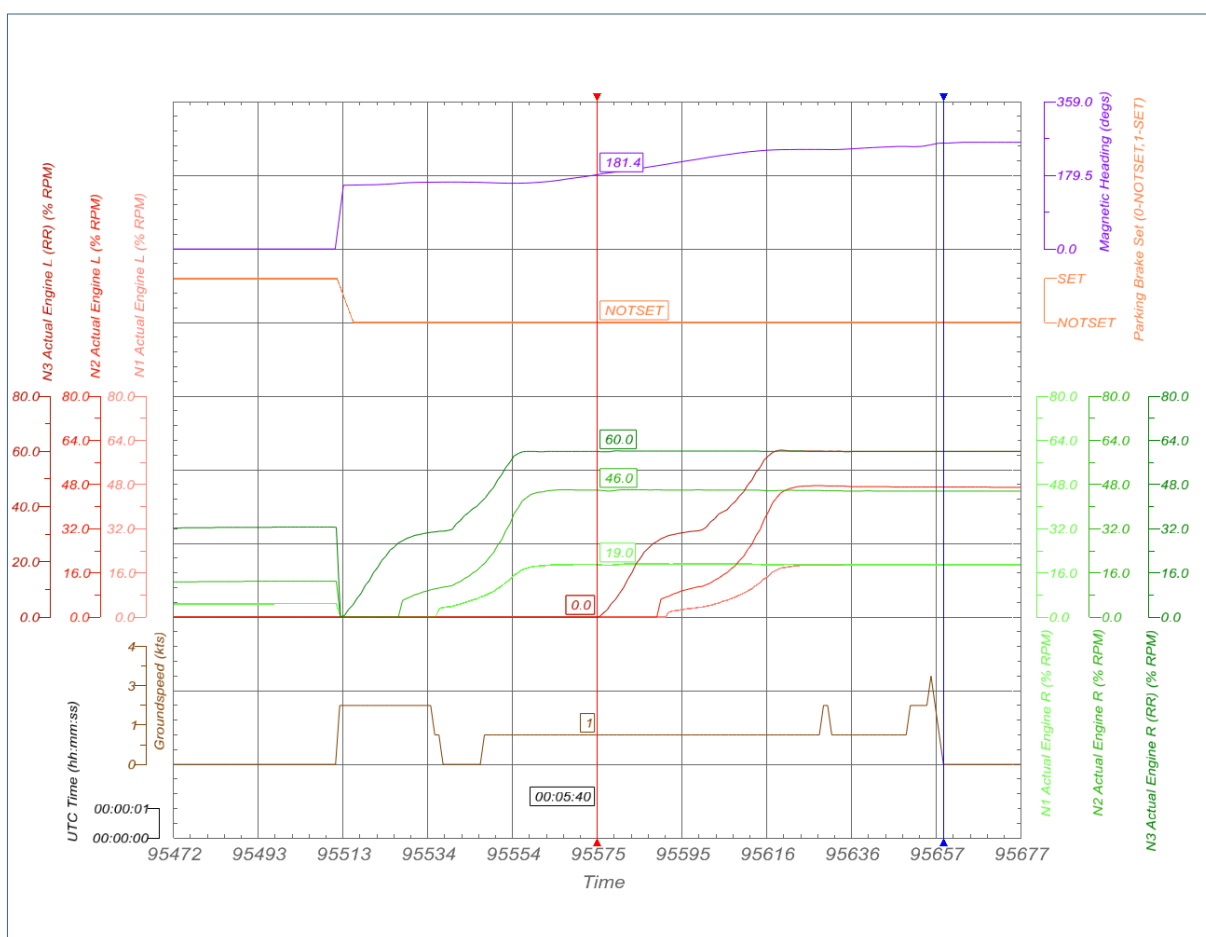


Fig. 16. Selected parameters during push-back and towing of Boeing B777-258 4X-ECC [source: FDR]

2.2. Impact of aircraft mass and engines thrust on pushback and towing operations.

When during towing an additional force (the thrust of the engines) was applied to the tractor-airplane combination – the speed of the combination increased (Fig. 16).

As long as the thrust of the engines is not enough to move the aircraft independently – the towbar is being stretched and despite the shearing of one of the pins, it fulfils its role. However, when a plane begins to move with its own engine thrust, and its speed becomes equal or higher than that of the tractor, the towbar is being compressed. In that situation, after shearing the pin, the rigid towbar-plane connection becomes an articulated joint that does not transmit the force moment, the drawbar is folded and a collision occurs.

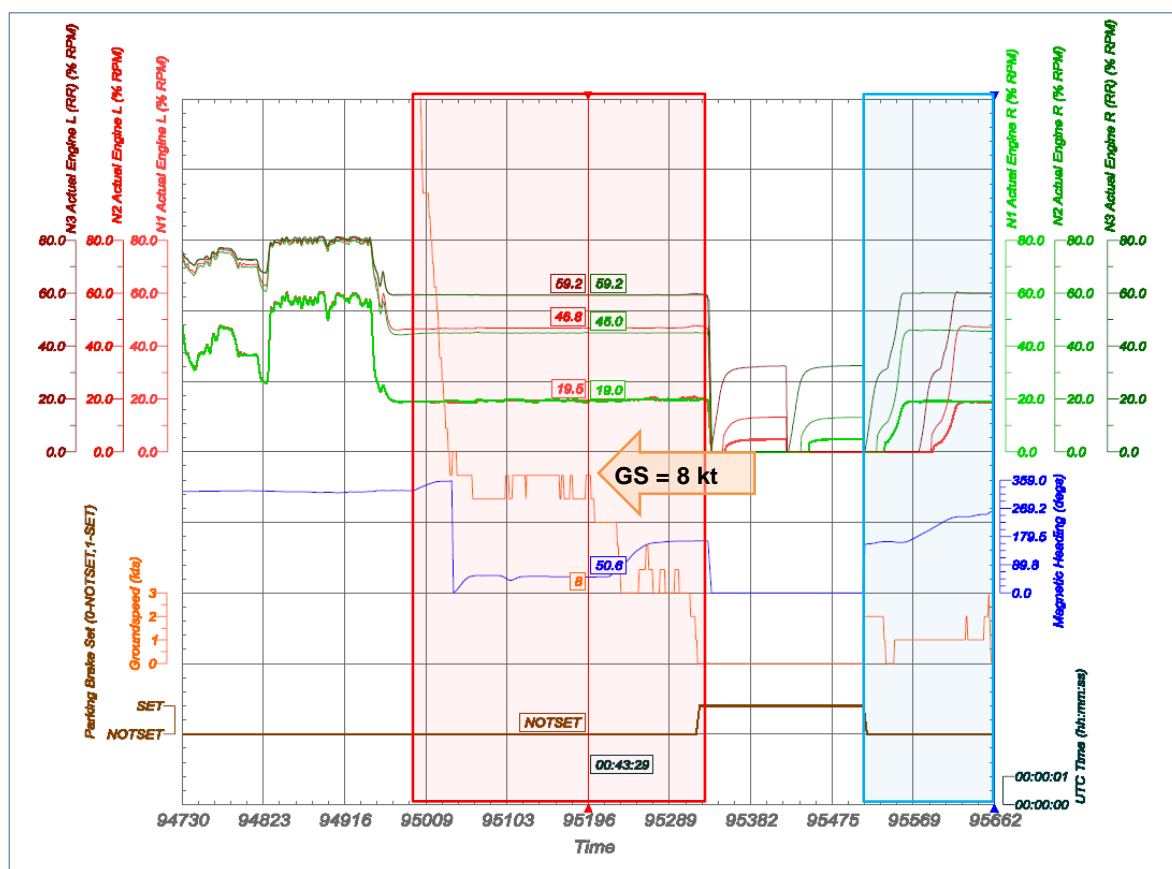


Fig. 17. Selected parameters of the Boeing B777-258 4X-ECC during taxiing (red frame) and during the occurrence (blue frame) [source: FDR]

Fig. 17 shows the course of selected parameters during the taxiing (red frame). For comparison, the blue frame shows the parameters during the occurrence. The analysis of the parameters shows that with both engines operating on IDLE setting, the plane was taxiing at a ground speed of 8 kt after landing (airplane ground speed (GS) – orange, left engine RPMs – red, right engine RPMs – green).

2.3. Towbar shear pins setting and the order of shearing them.

The shear pins of the towbar have circumferential grooves of various depths. Depending on the setting of the pins in the top or bottom position, the working cross-section area of the pin is greater for airplanes with greater mass (shallower groove) and respectively smaller for lighter planes (deeper groove). Therefore, the shear strength of the pins depends on their setting in relation to the head.

The position of each pin is locked with a ball lock in the bottom seat (Fig. 18-D). A spring presses the ball against the locking groove which is shown with yellow arrows in Fig. 18-A.

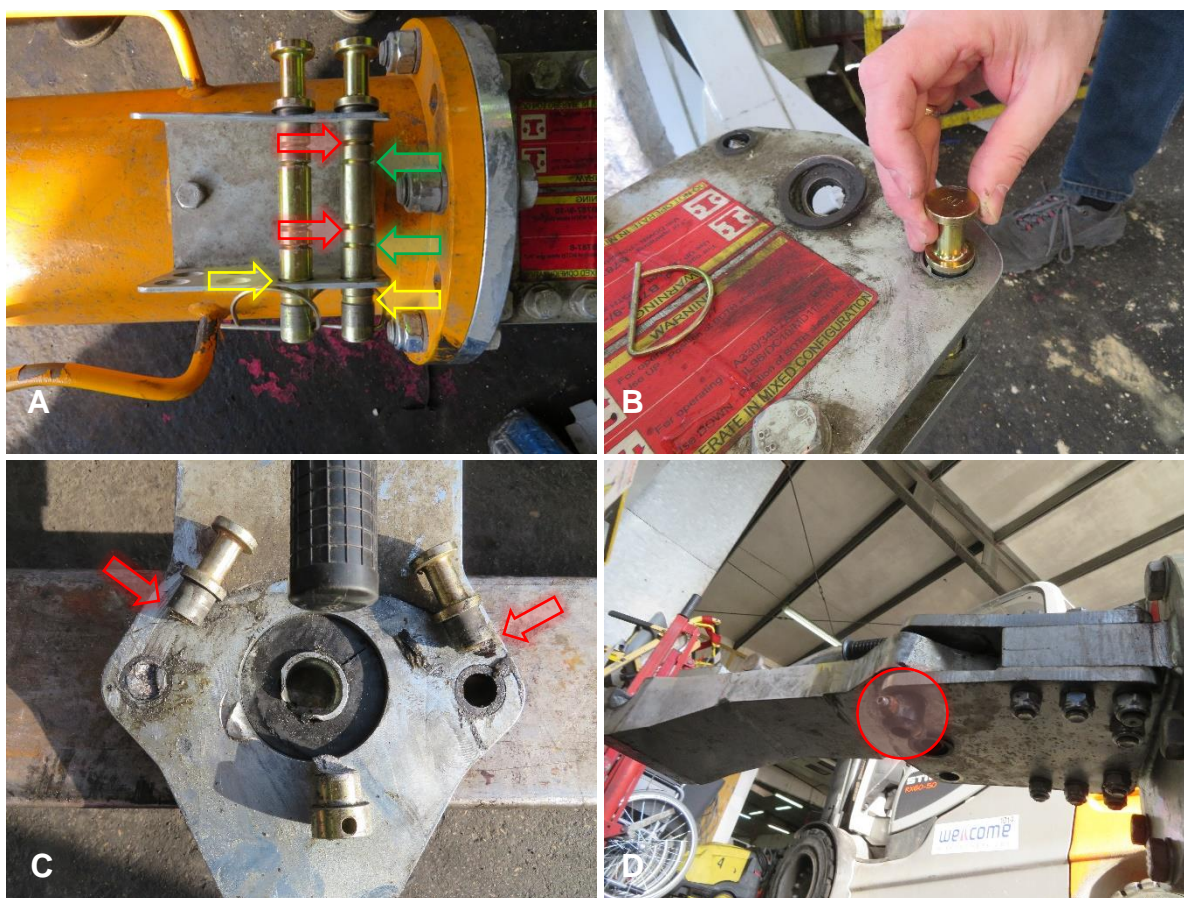


Fig. 18. J-TOWversa1-A towbar: A – undamaged shear pins (green arrows show the grooves at which the pins are sheared in the top setting, i.e. correct for B777; the red arrows show the grooves at which the pins were sheared during the occurrence; yellow arrows show the locking grooves); B – bottom position of the shear pin; C – upper fragments of the pins sheared during the occurrence; D – the lower seating of the right pin with a ball lock.

After exceeding the permissible load, the head of the towbar acts as a guillotine, shearing the bolts in the plane of the grooves. As shown above (Fig. 19-C) the pins have been sheared in the plane corresponding to their bottom position.

The left seating and fragments of the left pin were found on the apron (Fig. 5) in the place, where the tractor-plane combination made a right turn during towing (Fig. 1-G), which clearly determines the pin shearing location.

3. CONCLUSIONS

3.1. Findings

- 1) The aircraft had a valid Certificate of Airworthiness and was operated in accordance with the relevant regulations.
- 2) Pursuant to the applicable regulations and procedures, the aircraft was airworthy at the time of pushback.
- 3) The mass and center of gravity of the airplane were within the specified limits.
- 4) No evidence of aircraft defects or malfunctions that could have contributed to the occurrence was found.
- 5) During the push-back/towing operation the aircraft engines were started up and reached the IDLE RPM.
- 6) With both engines operating on the IDLE RPM, the airplane was able to move forward independently.
- 7) The aircraft was damaged to the extent requiring a repair.
- 8) The captain and FO had valid licenses and qualifications to perform the flight in accordance with the applicable regulations.
- 9) The captain and FO had valid aero-medical certificates and were rested before the flight.
- 10) After the occurrence, the crew allowed to overwrite the CVR recordings, which was inconsistent with the operator procedures and significantly hindered the assessment of the cooperation between the crew and the coordinator of the ground operation.
- 11) The start-up of both engines during pushback/towing was in accordance with the operator operational manual and agreed with the operation coordinator.
- 12) The flight crew conducted routine radio communication with the appropriate ATC units.
- 13) During the towing phase, in the course of a sharp right turn, the left shear pin of the towbar (external to the turn direction) was sheared.
- 14) The shearing of the pin was noticed by the personnel involved in the process of push-back/towing.
- 15) Despite the shearing of the pin, the towing operation was not aborted.
- 16) During towing, the operation coordinator was on the wrong (outer) side of the turn.
- 17) When the turn was completed, the tractor-aircraft combination was moving straight along in a straight line, slowed down by the tractor.
- 18) After shearing the pin, the connection of the towhead to the nose landing gear lost its stiffness and was unable to transfer the twisting moment to the nose landing gear strut.
- 19) Even when the towing tractor initiated the right turn towards TWY Z3, the plane continued to move straight, accelerating from 1 to 3 kt.
- 20) The aircraft, able to move on the IDLE RPM, collided with the tractor.

- 21) The raised cabin of the tractor damaged the skin of the nose, lower part of the fuselage.
- 22) The towbar pins used for the push-back/towing were appropriate for the operation.
- 23) The setting of the towbar shear pins was inconsistent with the towbar manual – the pins were set for an airplane of the mass lower than the incident airplane.
- 24) The tractor used for push-back/towing was selected in accordance with the handling agent instruction.
- 25) After the collision of the airplane with the tractor, the towing operation was aborted.
- 26) The operator procedures did not allow the replacement of ground handling agent personnel that had been verified by the operator prior to the operation.
- 27) The operator procedures required the presence of security agents during the aircraft preparation for a flight, which resulted in an additional psychological burden for handling agent personnel.
- 28) The operator procedures provided for shut down the CVR power after the occurrence.
- 29) At the time of the occurrence, the aerodrome lighting was working normally and had no impact on the course of the occurrence.
- 30) The apron in front of the VIP terminal on the military part of EPWA aerodrome has no painted lines for taxiing.
- 31) The aircraft was equipped with FDR, CVR and QAR.
- 32) The QAR was not made available to the Investigation Team.
- 33) The recordings of the CVR were overwritten as a result of failure to turn off the recorder power supply after the occurrence.
- 34) The lack of CVR recording prevented the Commission from assessing the communication between the crew and the operation coordinator.
- 35) No physiological factors were found to affect the performance of the flight crew.
- 36) Extended work time, unfavourable weather conditions, time of the day, stress related to operating the HEAD flight and operator procedures had adverse impact on the efficiency of ground handling agent personnel.
- 37) Nobody was injured during the occurrence.

3.2. Cause of the occurrence

The direct cause of the serious incident was lack of reaction to the shearing of the towbar pin and the continuation of the aircraft towing.

3.3. Contributing factors

- 1) Start-up of both engines during pushback-towing operation.
- 2) Setting of the towbar pins not compatible with the type of aircraft which was pushed-back and towed.

- 3) Fatigue of the ground handling staff caused by extended hours of work at night in adverse weather conditions.
- 4) Stress of ground handling staff due to servicing the HEAD status flight and procedures imposed by the operator.

4. SAFETY RECOMMENDATIONS

PKBWL has not proposed any safety recommendation after completion of the investigation

5. ANNEXES

None

THE END

Investigator-in-Charge

/digitally signed/